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CONTENTS AND INDEX.

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CONTENTS.

VOL. XXIX, July-December, 1902.

For alphabetical index, see page v.

No. 5. NOVEMBER.

No. 6. DECEMBER.

INDEX.

VOL. XXIX, July-December, 1902.

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STORAGE BATTERIES IN MILLS AND FACTORIES.

BY E. VAIL STEBBINS.

[Read before the Civil Engineers' Club of Cleveland, January 11, 1902.*]

THE function of a storage battery in a plant of any kind is that of a reservoir. It is an apparatus placed in circuit in an electric line, giving it relatively immense capacity to store up such energy as may be generated beyond the demands of the load at any given time, and to return this energy to the line when the demands exceed the average load.

This statement may seem superfluous, and yet there are many who do not grasp its complete significance. It is a fact that the laws of direct current electricity are practically identical with those of hydraulics, and the action of electric currents and the work they perform can be studied by exactly the same laws as water currents or air currents. The work done upon any D. C. electric circuit is the product of the volts and the amperes, the head or pressure times the volume of current, just as the available power of a waterfall is proportional to both the head and to the rate of flow. Inertia and velocity effects are similarly paralleled by the capacity and inductive effects in electricity, and, in fact, throughout the line the comparison exists.

This fact is brought out in order that the action of a battery on a line may be the more thoroughly understood and the result of its action appreciated. But there is another analogy that will assist in describing the aid rendered by a battery, and that is the use of an air chamber or standpipe. These, it is true, are really small reservoirs, but the property of varying the pressure is highly

*Manuscript received April 26, 1902.—Secretary, Ass'n of Eng. Socs.

developed, rather than the ability to take care of large amounts of fluid, and the resulting regulation is quite different in consequence. Now, the potential curve of a battery is quite similar to the com-

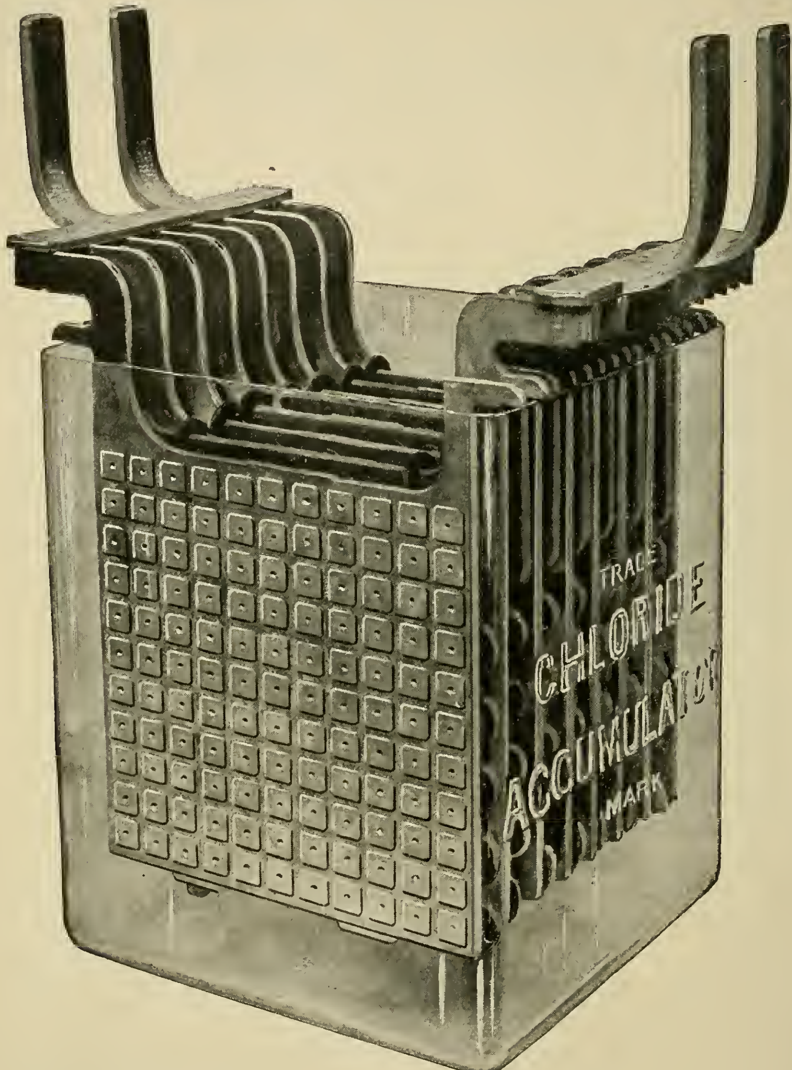


FIG. 1.

pression curve of an elastic fluid, and is, so to speak, in the same direction as that representing increase of pressure due to increase of head. In other words, as a battery fills up its terminal potential rises, and lowers as it discharges. The fact that the charging pressure, at a given state of charge, is somewhat higher than the corre-

sponding discharge pressure, aids in this effect and makes the equilibrium more stable. Thus these two important functions of common hydraulic accessories may be duplicated in electric installations with the same beneficial results.

I suppose no competent engineer would attempt to operate a gas plant without including gasometers or tanks of some kind in his outfit any more than he would try to supply a city with

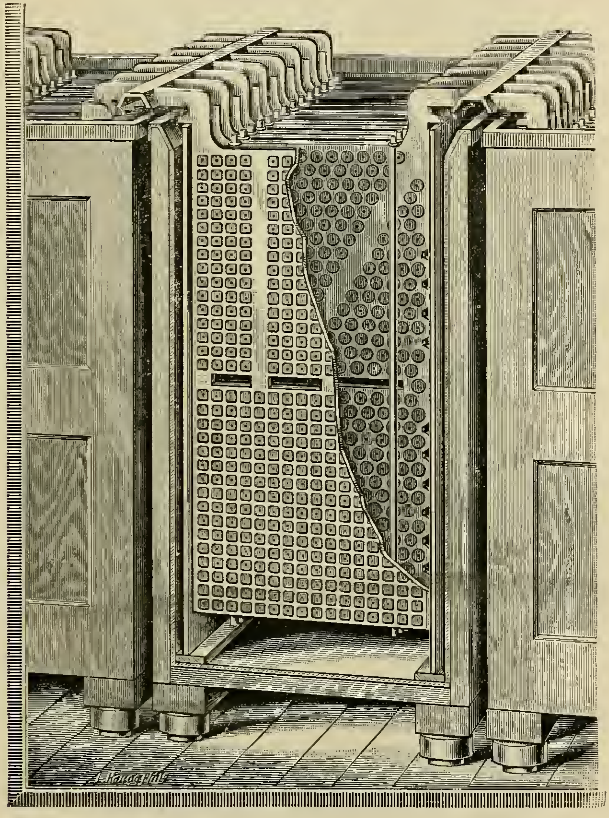


FIG. 2.

water from a pumping station unprovided with a proper dam, or reservoir, or standpipe to regulate the demands upon his pumps. A retort that was worked hard to supply the evening load of a gas company, and run almost idle to keep pressure on the lines by day without the assistance of tanks, would not only give variable pressure and poor service, but would work most inefficiently. Likewise, if a pumping station were operated in a similar manner, water hammer, variable pressure, inability to meet the maximum

demand and very poor economy would be only a few of the resulting defects. Add to this a very variable load, jumping, perhaps, from zero to maximum and back to zero in a few seconds, and the work done by many electric stations will be appreciated.

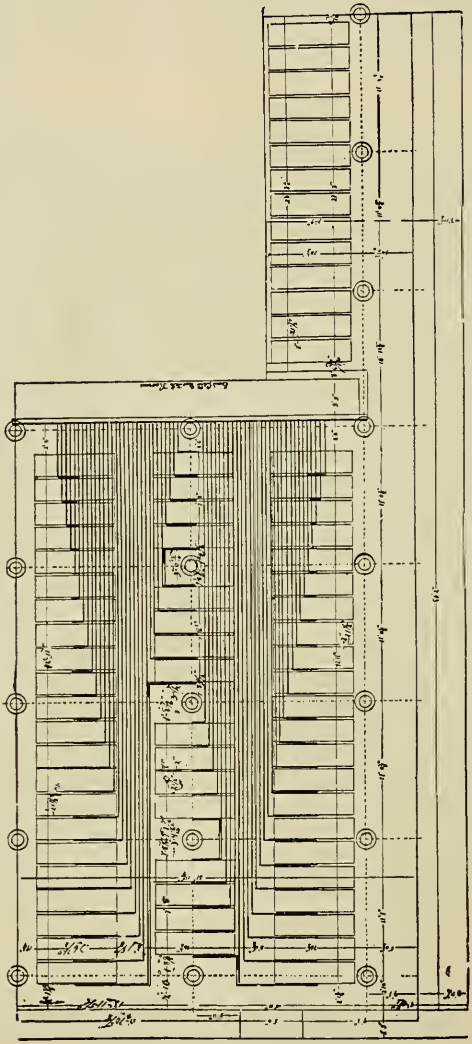


Fig. 3.

This explains the poor economy of operation of many railways and other electric plants, and shows at once the cause of poor pressure, flickering lamps, sudden breakdowns, etc.

The development of the storage battery has alleviated these difficulties to a very large extent, and has made it possible to

operate power and lights from the same system without undue flickering of the lamps; it has also made it possible to operate highly fluctuating loads on a minimum amount of generating apparatus; and, as these two properties are the ones most needful in mill and factory work, we are brought to the immediate subject of this paper.

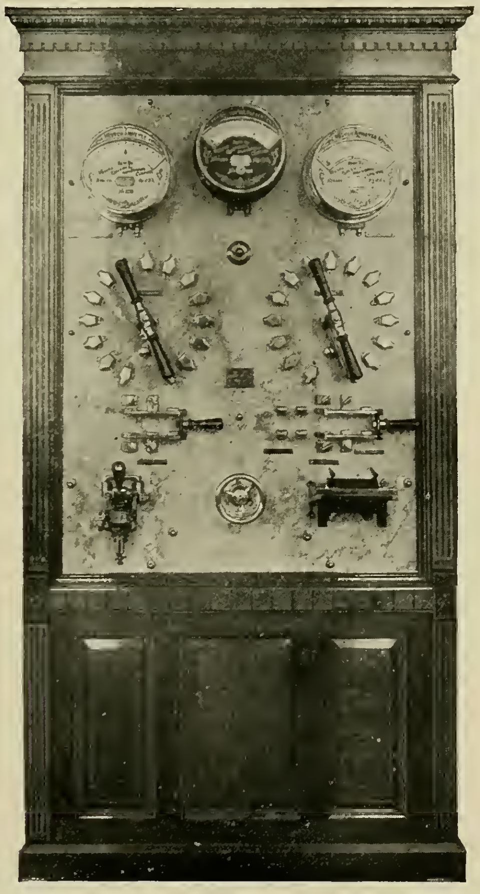


FIG. 4.

Before proceeding, however, it seems advisable to look into the construction of a battery a little and see exactly what its action is.

Essentially, a battery consists of positive and negative electrodes in a containing vessel immersed in electrolyte of some kind.

In other words, we have the positive group, consisting of a given number of positive plates, burned in multiple to a "T" strap

or bus bar, and the negative group, consisting of the same number (plus one) of negative plates, burned together in like manner.

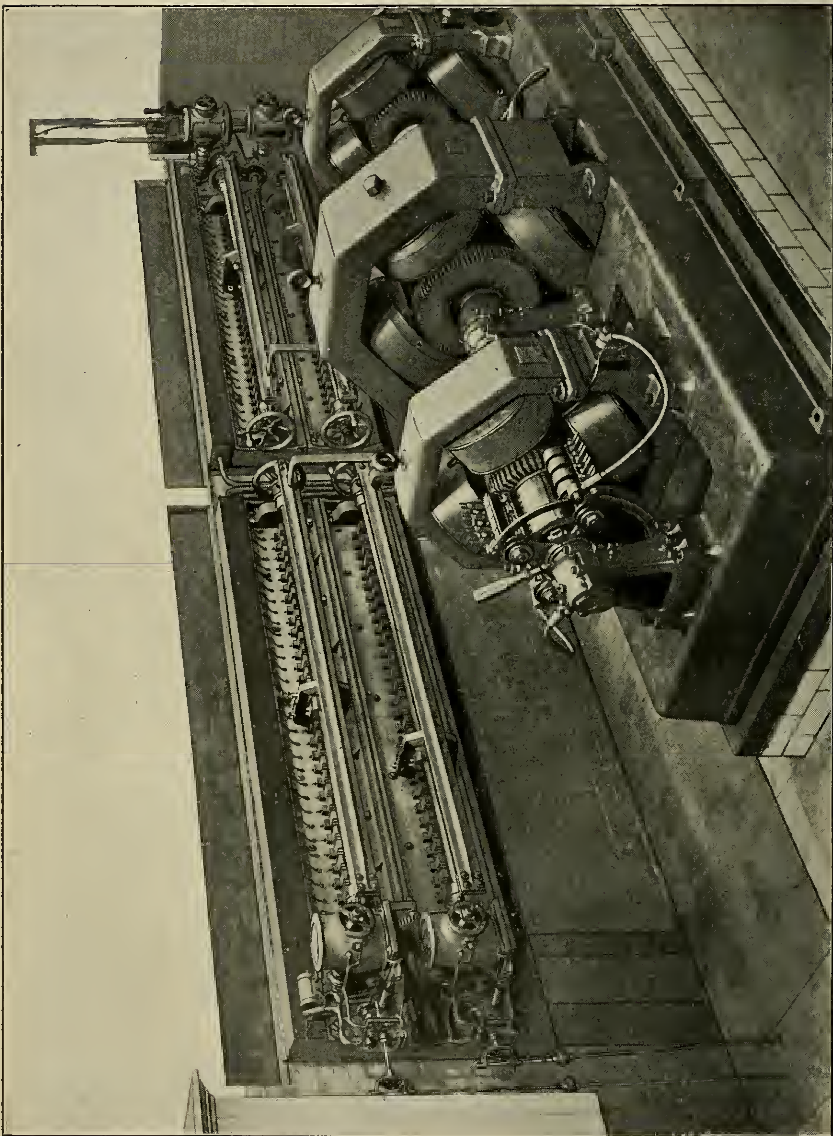


Fig. 5.

Both of these groups are placed in either a glass jar, a wooden lead-lined tank or a metallic alloy tank, which vessel is then filled with sulphuric acid of the proper density. This is generally in the neighborhood of 1150 s. g. when the battery is discharged,

and 1200 s. g. after the battery is completely charged. The various cells, as here described, are then connected in series to

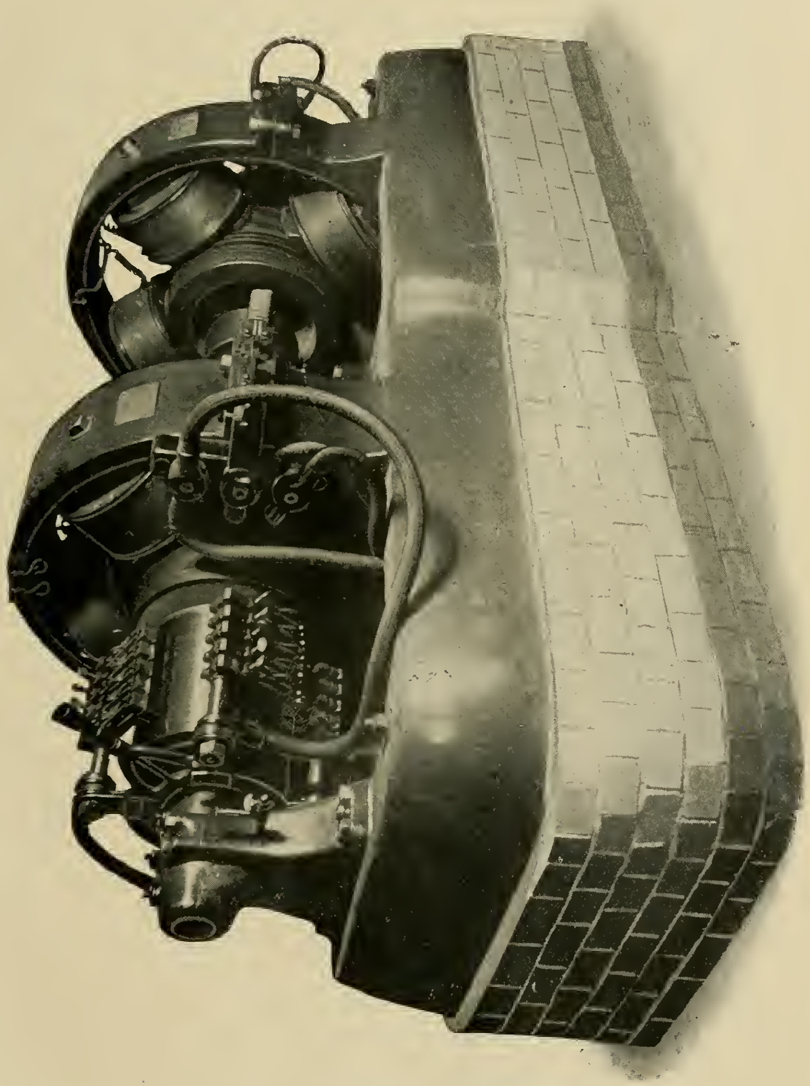


FIG. 6.

the proper number for giving the voltage required. They are set upon racks or stringers, hereinafter described, with the necessary insulators, etc.

As above stated, the number of cells determines the voltage, and the size and number of plates per cell the capacity. At the

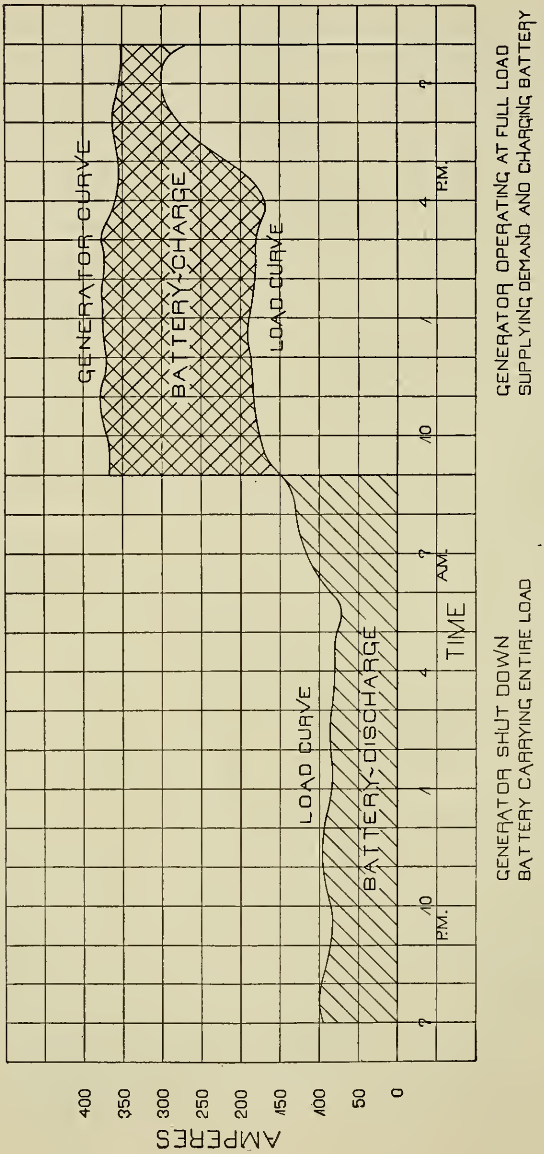


Fig. 7.

commencement of discharge a single cell has a terminal potential amounting to approximately 2.1 volts. As the cell discharges, this gradually drops to two volts, which may be called the average potential during discharge. As it empties, however, the potential

again falls off considerably, until a final potential is obtained considerably below this point, and varying with the rate at which the current has been consumed. A cell which has been discharged at the eight-hour rate, which is normal, will drop to about 1.8 volts. Should the current, however, be taken out at the five-hour rate of discharge, the terminal potential will be found to be 1.75. A three-hour rate of discharge gives us 1.7, etc. Therefore, in designing a battery for this character of straight discharging, the number of cells will depend on the rate at which the current is used. A battery where it is expected to take the discharge at the eight-hour rate will consequently require a smaller number of cells than one where the total output is to be used in three or four hours. Likewise, in regulating work, where a battery charges and discharges at high rates for a very few minutes, without by any means exhausting the capacity of the battery, and where the size of the cell is determined rather by what the battery will stand in the way of sudden and excessive rates of flow, the voltage must be so adjusted as to average the charge and discharge conditions, and the number of cells is in this case so determined that the bus pressure will give this average per cell when the battery is quiescent. The size of the cell is of course determined by the number of plates and by the size of each plate. As a rule, the cells should not be allowed to get too long, in view of the difficulty in caring for them, and, when so many plates have been put into a cell as to make it difficult to reach across it, it is better to increase the size of the plate and use fewer plates per cell. Where the rate of discharge is to be constant for considerable periods of time, it is possible to use an oblong plate in order to economize space; but for ordinary conditions of work the square plate will be found to be much more satisfactory, and it is generally used, except in large Edison stations and similar plants, where the conditions render a type "H" plate particularly applicable.

All of the plates of either polarity are burned to bus bars or T straps and are held apart by some sort of separator.

The positive plate consists, primarily, of a grid, in which the active material is held. This grid is composed of an antimonious lead compound which is almost as stiff as brass, and not only tends to resist bending or buckling, but is further only very slightly susceptible to the action of sulphuric acid. This prevents deterioration, due to distortion of the plate, and also such as would follow were the grid eaten into by the electrolyte, under charge. The grid, as cast, contains many round holes, set in hexagonal pattern, and into these holes are forced spirals, formed

of corrugated lead ribbon. These corrugations are made so as to give a great deal of surface to the button and to allow the acid to pass completely through the plate, and the holes are so formed that the swelling of the button, under the process of oxidization, dovetails it firmly into the grid. It will be noticed that, as these buttons go completely through the plate, the action of the acid is equal on all parts of the active material, and, consequently, a greater oxidization cannot take place on one side of

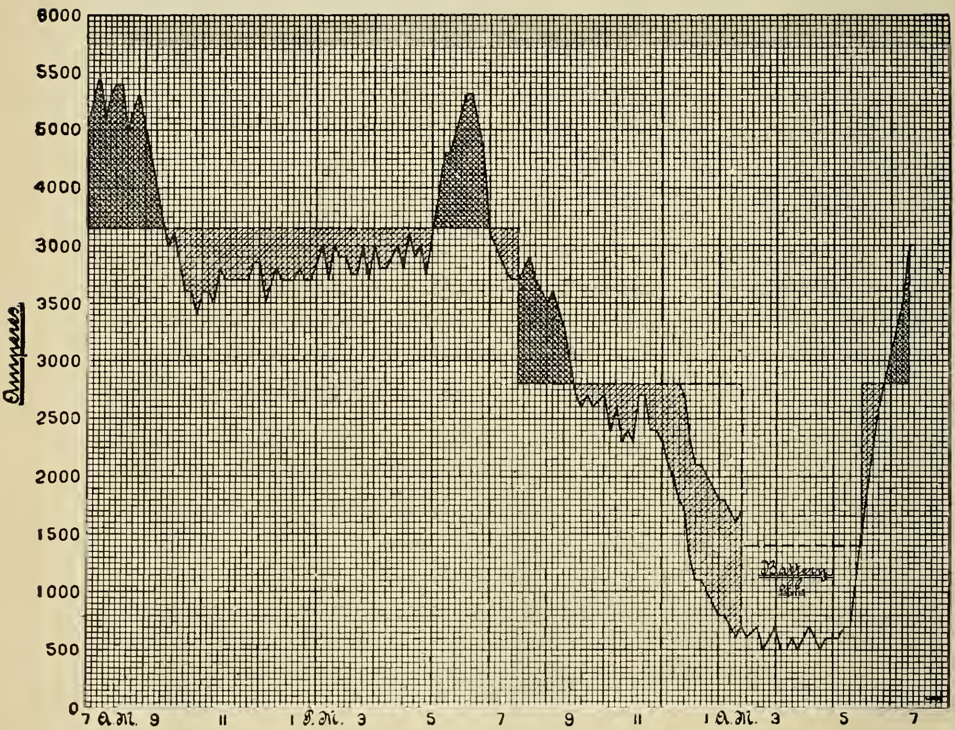


FIG. 8.

the plate than on the other. Were the plates so made that the active material on the two sides of the plate was separated, such a condition of affairs would be found to cause uneven formation of the lead oxide, the growth of which would very promptly give the plate that curvature known as buckling, which results in throwing off the active material, short-circuiting the cell and the many other difficulties to which storage batteries in the earlier stages were subject.

The negative plate consists of a like lead antimony grid, except that the holes in this case are square and the grid is cast

around the buttons of active material which, in the primitive state, consists of a mixture of lead and zinc chloride. In the finished plate the zinc and chlorine have been chemically removed, leaving the lead in a spongy mass, which is highly absorptive and presents an enormous internal surface. It will be noticed that on wetting one of these negative plates the buttons will absorb the moisture like blotting paper and present a practically dry surface, whereas the grid will remain wet. Quite different from the positive plate, the negative grid is cast around the buttons, and these are therefore made larger at the center than at the outer edges, the result being that the negative button is dovetailed into the grid, but in a reverse manner, so to speak, from the positive buttons.

It is necessary that all the plates should be kept well apart from one another. The difference of potential between positive and negative groups may be represented as the sum of the difference of potential between each plate and the electrolyte. If, therefore, a positive plate is allowed to touch a negative plate, or, if short circuits are allowed to form between, the cell will promptly discharge within itself, resulting in rapid deterioration and also, of course, in loss of charge.

When the elements are installed in glass jars, hard-rubber "ring" separators are used. These consist of an oblong-shaped piece of rubber, with a hole cut through the center of it, which may be slipped over the positive plate. Two of these are placed on the ends of the positive plates and serve to hold all the plates thoroughly separated in the jar. Where the elements are installed in tanks, glass tube separators are used, two tubes being placed between each pair of adjacent plates. Fig. 1 shows an element installed in a glass jar. From this it will be seen that the negative plates are all burned to a double tee strap at the left, while the positive plates are similarly burned together at the right. The ends of the hard-rubber separators over the positive plates are also discernible. Fig. 2 shows a cell installed in a lead-lined tank. Here the method of burning the plates to a lead bus bar, instead of using tee straps, is shown. The arrangement of the buttons on both the positive and negative plates is also clearly illustrated, and the glass tube separators between the plates may be plainly seen. In Fig. 1 it may be noticed that the plates rest directly upon the edge of the glass jar. In Fig. 2, however, where a lead-lined tank has been used, sheets of glass are inserted to support the plates, as they would otherwise all be short-circuited against the lead lining of the containing vessel. In these wooden tanks no metal of any kind, save the lead lining, is used; iron being very

detrimental to a storage battery, as is also copper, no nails of any kind are used, and the sides and bottom of the tank are all grooved and dovetailed into place. The lead lining is very carefully burned up so as to avoid any possible leaks, and the more modern tanks are so designed that any spilled acid may not remain in contact with the wood and cause deterioration.

We will now take up the charge and discharge curves of a battery. It will be noticed that when a battery is completely charged it will commence to discharge at a pretty high voltage.

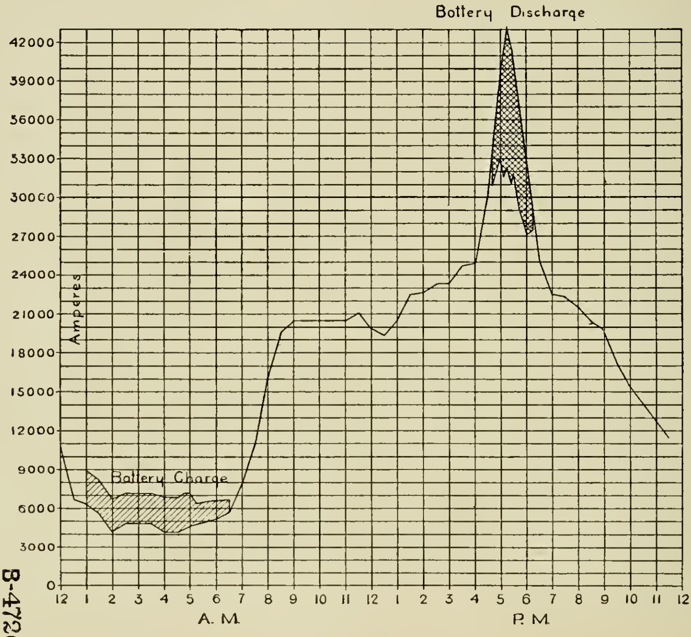


Fig. 9.

This falls off, however, almost immediately in a slight degree, and the curve runs along at an almost constant voltage, dropping slightly till the cell is pretty well emptied, when the pressure again falls off rapidly. Now, if these charges were not compensated for, it would be impossible to maintain a constant potential across the bus bars. There are several ways of doing this. First, by the use of end cells; second, by means of counter cells; third, by means of various specially wound boosters, and, finally, by the separation of circuits, the introduction of resistances and various combinations of these schemes.

The term "end cells" is self-explanatory. It means that a certain number of cells on the end of a battery have individual

connections to the bus bar through an end-cell switch, by which the battery current may be allowed to pass through any desired number of cells, thereby gradually reducing or increasing the number of cells in series. As each cell represents a given voltage at any state of discharge, the voltage maintained across the bus by the battery may be maintained constant, provided the end cells are thrown in or out, so as to counterbalance the change in voltage of the cells due to the amount of current which has been taken from them. Thus, for example, a battery containing say sixty-four cells, of which thirteen are end cells, would commence discharging with the thirteen end cells all thrown out, or only fifty-one cells operating. As the voltage dropped off, one cell would be thrown in, then another, and a third and so on until at the end of discharge as many cells would be thrown in as was found necessary to maintain the voltage desired at the bus.

Where batteries are of large size, and a considerable number of end cells are used, these string out to quite a distance, and considerable copper is used in making a connection from each end cell to the board of sufficient capacity to carry the entire output of the battery. Under these circumstances, it is of course desirable to place the end cells as close to the board as is practicable. Fig. 3 shows an arrangement of this sort. Here the end cells are placed on the ends of three rows of the battery, the connections from each one being brought to the board on which is located the end-cell switch. It will readily be seen from this arrangement how much copper has been saved over what would have been the case had the cells all been arranged in line on the last row of the battery. Fig. 4 shows a switchboard on which are mounted two round-pattern end-cell switches. It will be seen that by turning the handles of these switches the contact will be revolved around the entire set of points to which the end cells are connected. It is necessary, in all end-cell switches, to have a short-circuiting resistance attached to the main contact, for in passing from one cell to another it is necessary either to disconnect the battery or else to short-circuit a cell. Disconnecting the battery would cause bad flickering of the lights, whereas direct short-circuiting of the cell would tend to rapidly deteriorate it. The short-circuiting resistance, generally made of German silver, allows the cell to be short-circuited through it, and the consequent flow is very small, all damage to the cell being thereby prevented. Fig. 5 shows four horizontal-type motor-driven end-cell switches, used on larger sizes of battery. In the foreground is also shown a motor-driven double shunt booster. The entire outfit in this illustration is for

charging and discharging a storage battery installed upon a three-wire system, two of the end-cell switches being used to charge the two sides of the battery through the double booster, while the other two end-cell switches are used for discharging.

In smaller batteries counter cells may be used. These consist of grids, in which no active material has been placed, but are otherwise exactly like the standard cells. The very slight coating

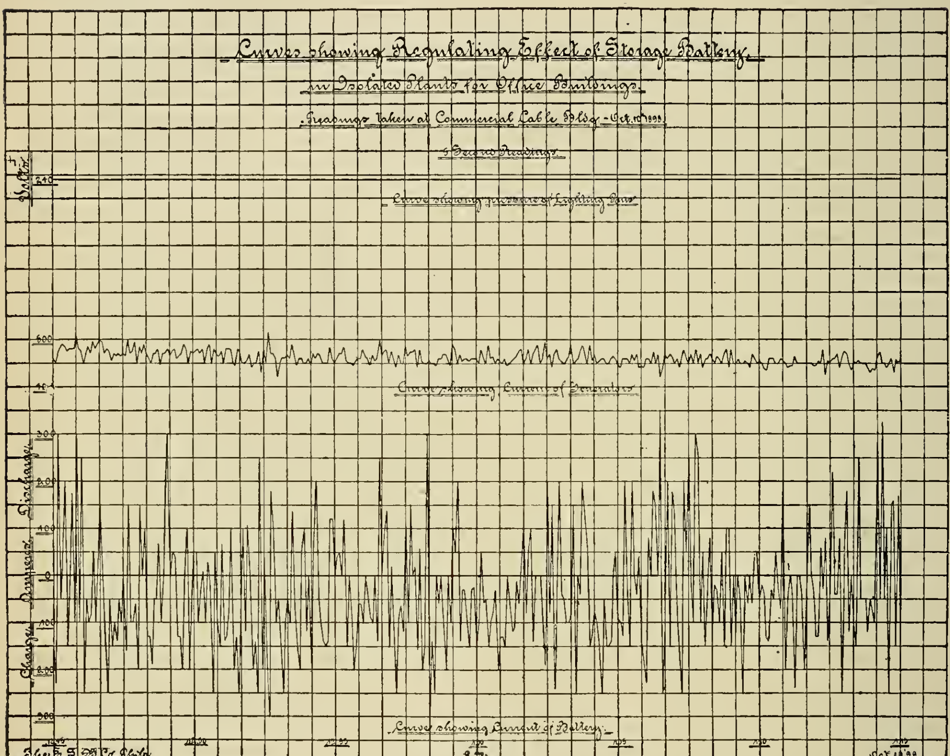


FIG. 10.

of oxide on the grid is sufficient to give a counter electro-motive force, but the cell cannot be discharged, as it has practically no capacity whatever. From 2.3 to 2.5 volts is the difference of potential obtained from a counter cell. Of course, in this case the entire battery is connected in, all of the counter cells being used to oppose it at the commencement of discharge, and (quite the contrary in the method of procedure in the case of the end cells) these counter cells are thrown out of circuit as the voltage of the battery goes down under discharge.

Fig. 6 illustrates a motor-driven booster. The function of this machine is to regulate the charge or the discharge of a battery, or in some cases both. Boosters are also designed to give a constant current in special classes of work taken up later.

Taking up these various methods of regulating the battery, then, in their order, we find that the end cell and counter cell or rheostat connections are generally used where a battery is to be used on peak work or to carry night load when the plant is shut down. In many factories the capacity of the plant is practically all used to operate machinery; consequently, when the lights are thrown on, the plant is overloaded and breakdowns are frequent. Now, a battery can be slowly charged all day whenever there is a little surplus power, and in the evening it will assist the generator in carrying the additional load. Such additions are frequently made where millowners wish to increase the capacity, adding more motors or more lights to an installation which already taxes the plant to its full capacity during peak loads. Another boiler may seem desirable, or another engine or generator, and yet the engineers do not care to advise the purchase, as perhaps the present plant is only half loaded during the major part of the day. New generating machinery would, when in use, not operate fully loaded, and would, therefore, be uneconomical, while during the main portion of the day the present machinery is not giving the best results for like reasons. Let us examine the curve showing the relation of the coal consumption per kilowatt hour to the load factor of the engine. From this it will readily be seen how quickly the coal consumption per unit of work increases as the load on the engine is allowed to drop further and further below its rating. Overloading an engine too much likewise increases the coal per kilowatt hour, but this is not so important, because it is less apt to be done. Now, by charging when the load is light and discharging when heavy, the engine operating may be kept approximately fully loaded all the time. The curves here shown in Figs. 7, 8 and 9 are from various classes of work, and show how, under varying external loads, giving peaks of considerable duration, the machines may, nevertheless, be kept fairly constant at full load.

The end-cell switches are operated manually or by a motor, throwing cells in or out in such numbers as to make the battery carry any quantity of the load which the engineer may desire.

Now, in very small installations, this same regulation may be obtained through the use of a rheostat, thereby saving the expense of the end-cell connections, although this method is less economical, owing to the C^2R losses in the resistance.

When exceedingly close regulation is required, the counter cells are used. They respond very readily to changes of current, maintaining very constant voltage at the lamps, and giving the entire system an elasticity not obtainable in any other way. Owing to the increased total number of cells, however, they are rarely installed in very large battery plants. These cells have a relatively large electro-motive force, with very small capacity, while end cells have the same electro-motive force and capacity as the rest of the cells.

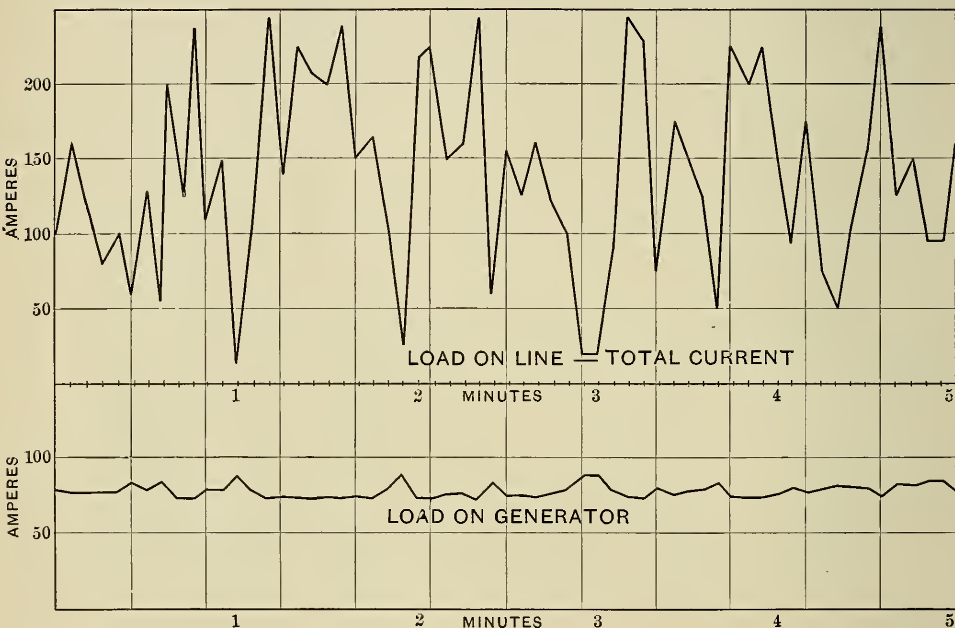


FIG. 11.

We now come to a class of work where highly fluctuating loads are to be dealt with. Many factories are equipped with cranes of high power, elevators, locomotives, etc., which do not average much power, but, on starting with a full load, take enormous inrushes of current. These will make the engines pound and grind, with an accompaniment of flickering lights, slowing of motors and many other unsatisfactory disturbances of the service. In cases of this sort a scheme is generally adopted of placing all the lights and other constant loads across the generator bus and the fluctuating motors, etc., on a separate bus. The battery is across the variable load bus, with a constant current booster supplying the current from the generator bus. In this manner

the average current of the variable load is supplied as a constant load, the battery taking the average current to charge, in the intervals when there is little or no call for current, and discharging heavily when the momentary peaks come on, thus adding

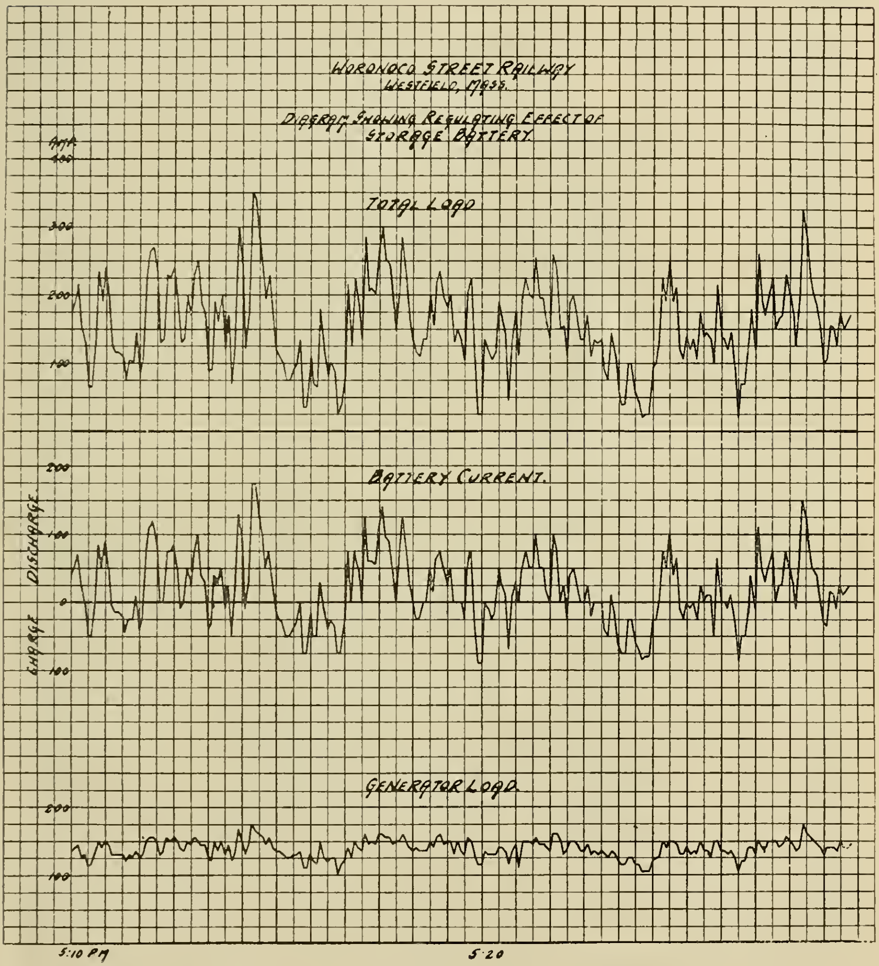


FIG. 12.

to the average current supplied by the constant current booster enough to meet the demands. This requires a relatively small regulating battery and greatly reduces the amount of generating machinery needed. It maintains a constant load on the generators, insuring a steady light and a steady high-load factor, with excellent economy of operation in consequence. At night, or when-

ever the fluctuating load ceases, the two sets of busses may be tied together, cutting out the constant current booster, and the battery may be used as previously described. Fig. 10 shows the results of such an installation in regulating elevator fluctuations.

When the average current varies greatly, a better scheme has been devised, which consists in putting a differential or compound booster in series with the battery and causing it to charge or discharge the battery, according to the requirements of the

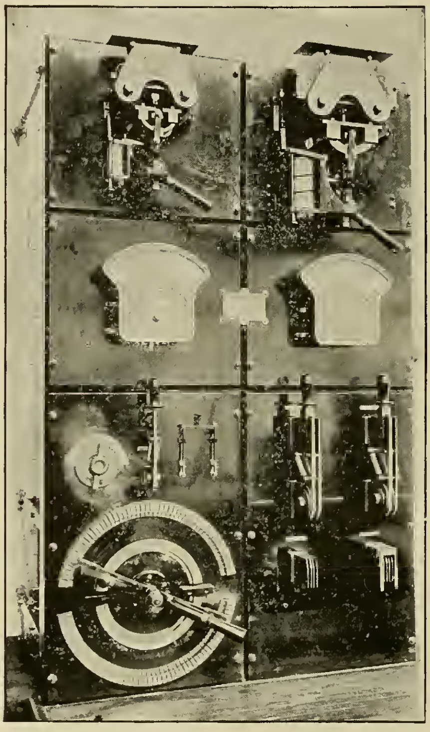


Fig. 13.

external load. By this means the output of the machinery can be regulated to within ten per cent. of any given amount. This scheme is used largely on railway work, and is perhaps more suited to it than to factory practice, although it has been used with great success in a number of plants when the constant current scheme could not be readily adapted. Figs. 11 and 12 show results so obtained. Fig. 13 shows a switchboard used with boosters of this class, and I would call particular attention to the reversing rheostat specially devised to obviate the necessity of opening the field circuit.

We will now look at the construction of batteries as variously installed. Fig. 14 shows the battery in the Arnold Print Works installed in glass. As will be here seen, the cells are mounted on

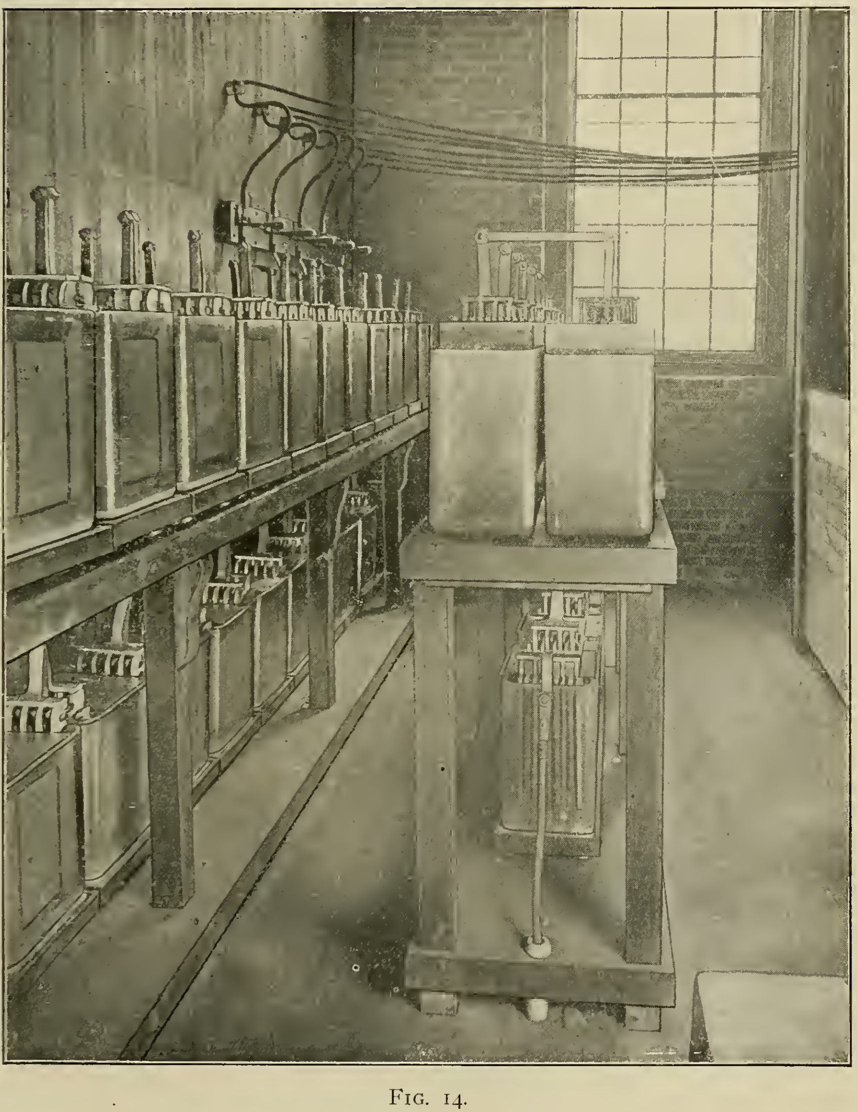


Fig. 14.

sand trays, supported by insulators, the whole being put upon wooden racks which are thoroughly coated with acid-proof paint. This is necessary in order that any acid which slops over may not attack the wood. The floor of the room is made of cement,

vitrified brick, tile or some other acid-proof material. In the farther end of the room may be seen a number of the end-cell

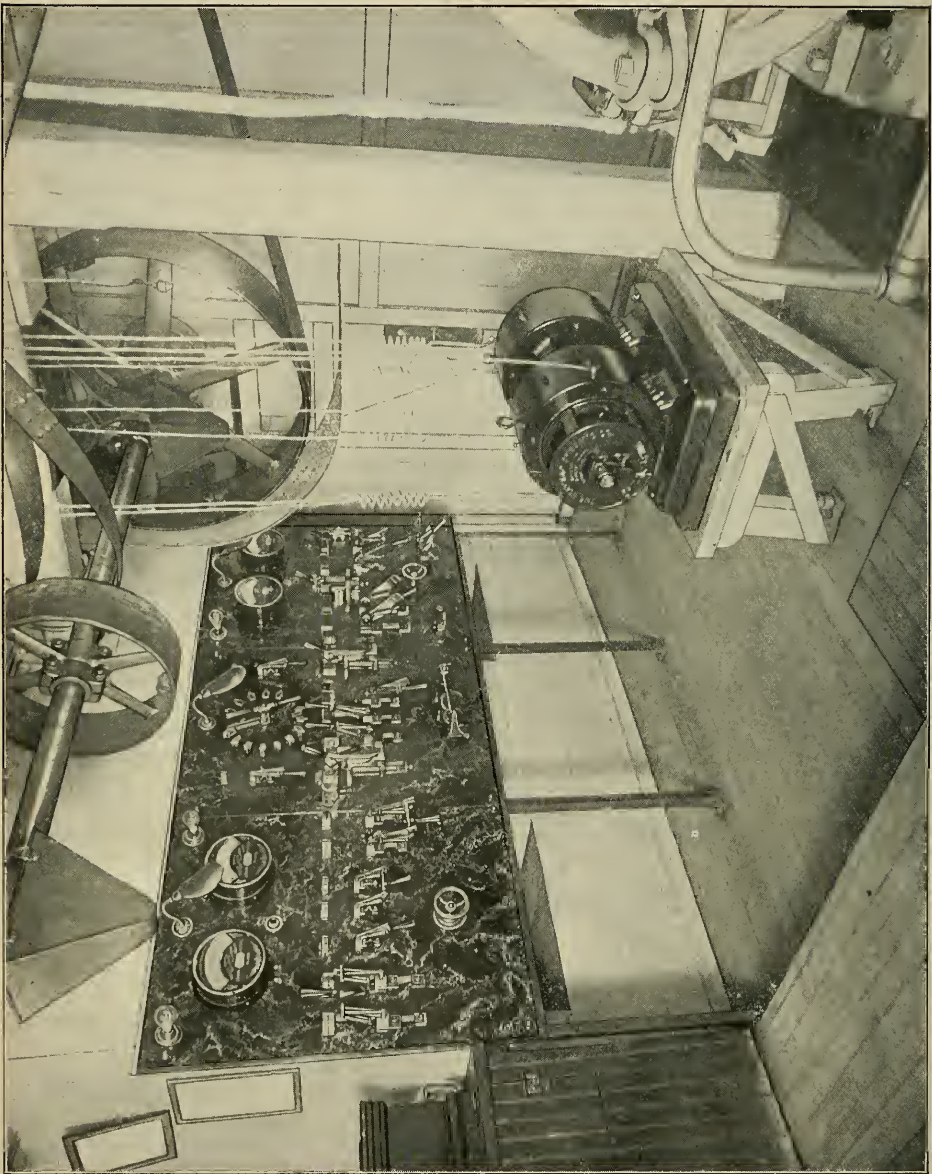


Fig. 15.

connections going from the terminal cells of the battery over to the switchboard. Fig. 15 shows the switchboard and booster operated with this battery.

Fig. 16 is the battery of Messrs. R. & H. Simon, at Union Hill, N. J. This battery is considerably larger than that of the

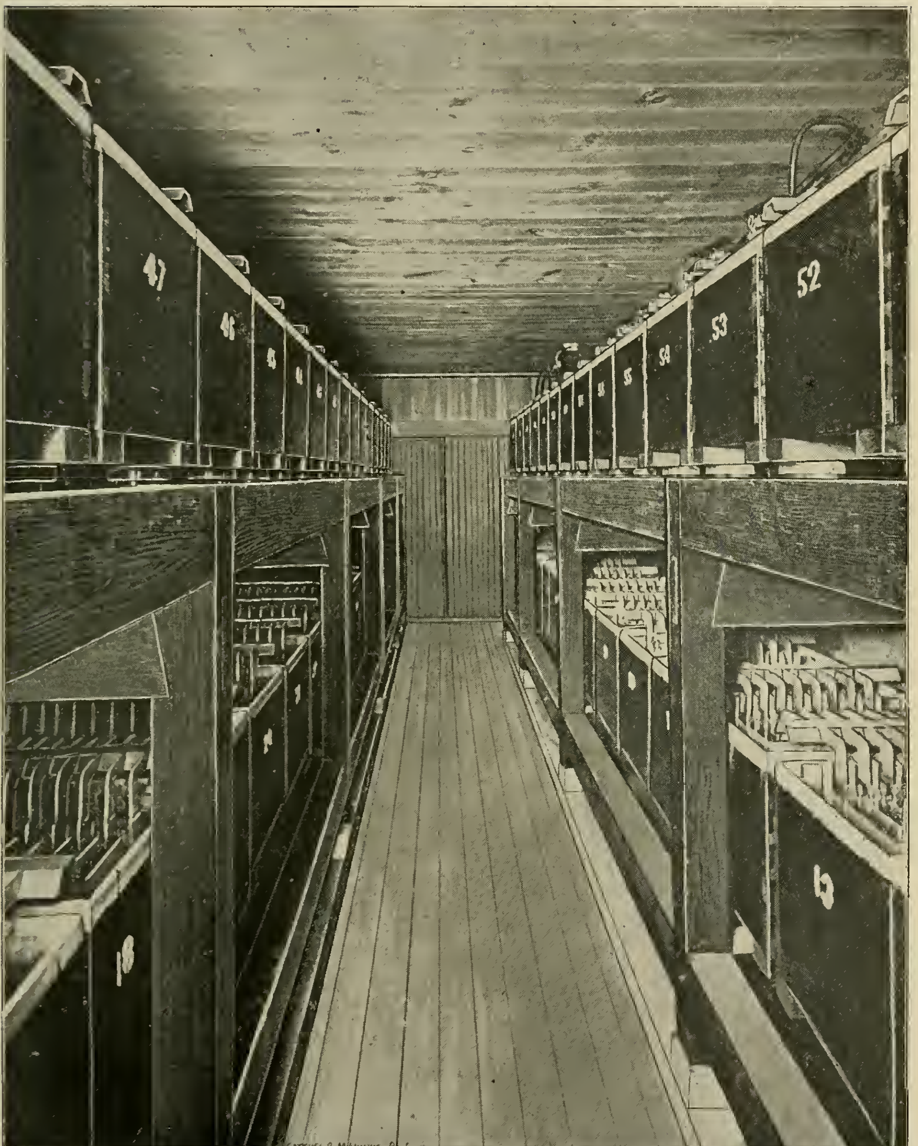


FIG. 16.

Arnold Print Works, and is installed in lead-lined tanks. These, it will be seen, do not need the sand trays, and are mounted directly on the racks with large glass insulators.

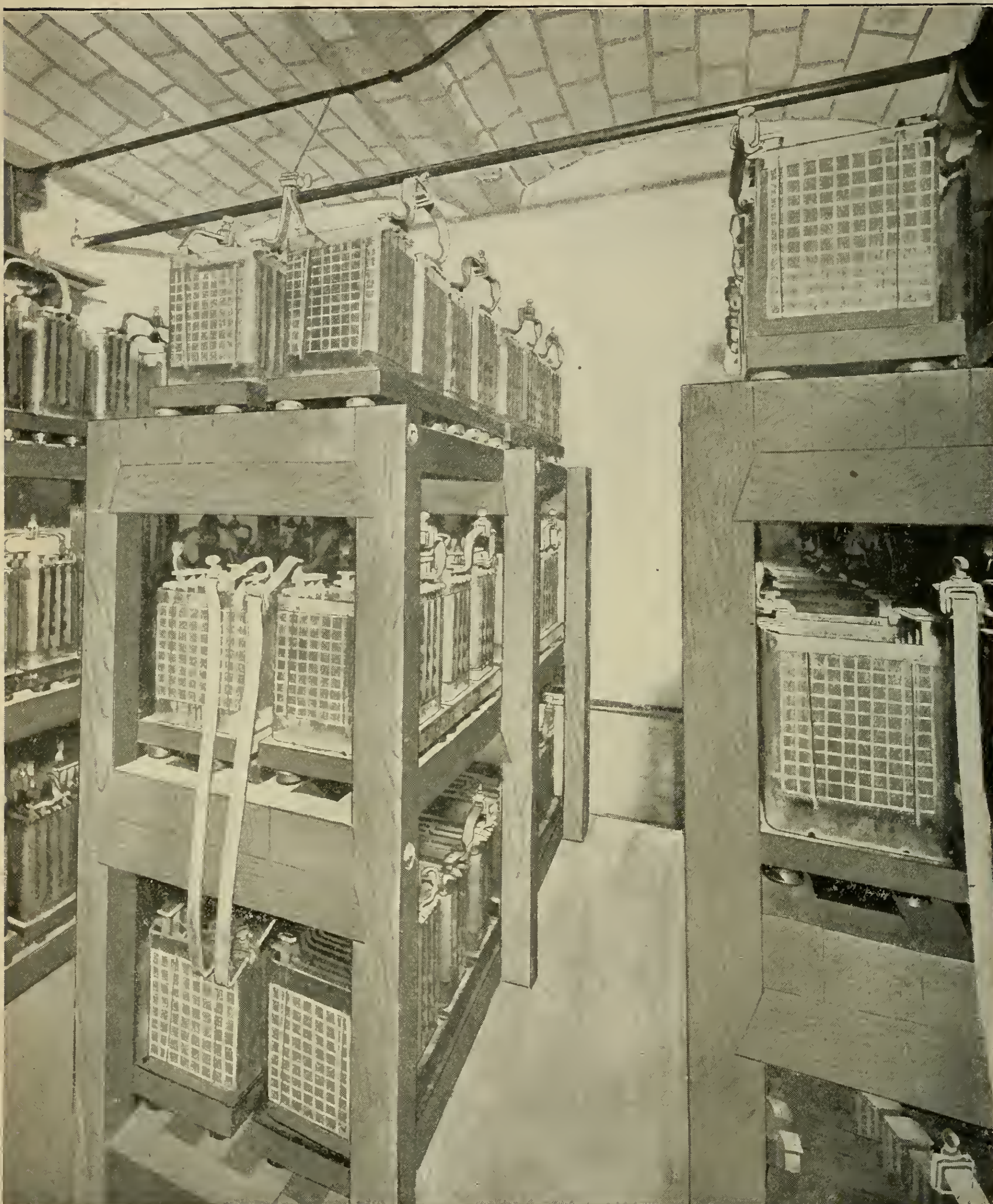


Fig. 17.

Fig. 17 shows the battery installed in the mill of Jones Bros., and is like the first one, a smaller battery installed in glass. The terminal connections between the rows are very clearly shown here.

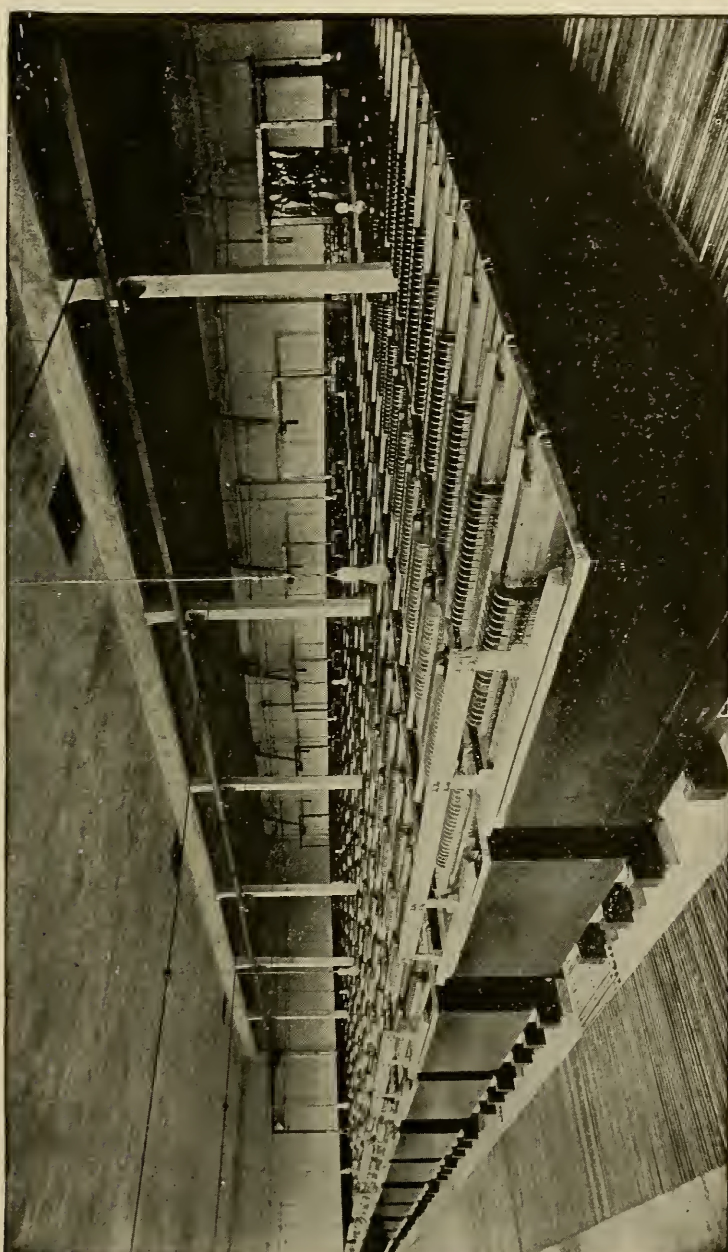
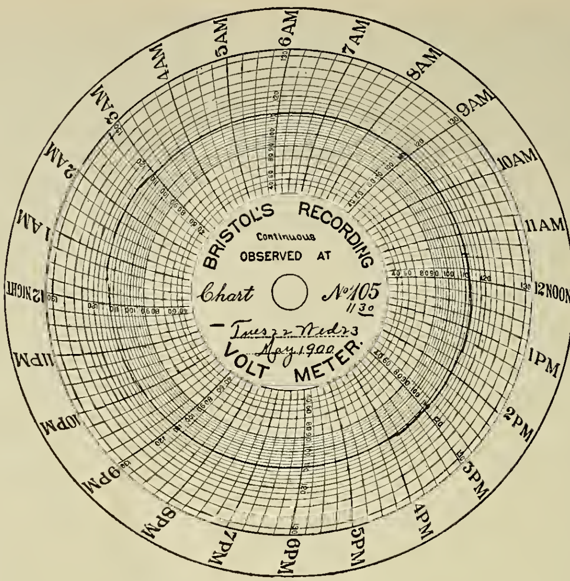


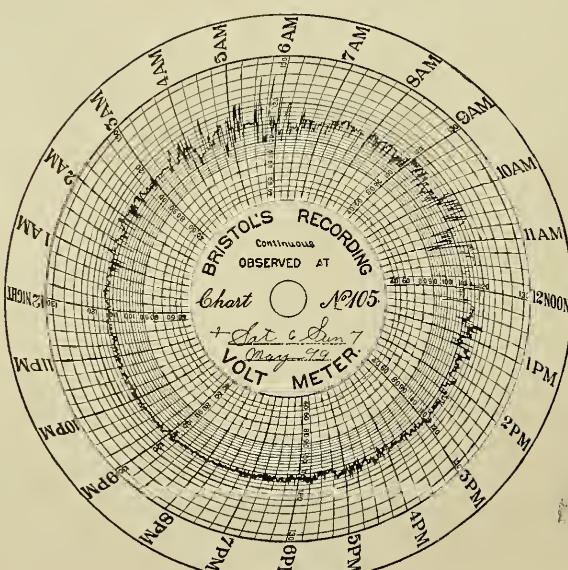
Fig. 18.

From these illustrations a very fair idea of the method of installing batteries can be obtained.

It is sometimes desirable to install a battery before the mill is completed and at a time when the average or varying load



After Installation of Battery.



Before Installation of Battery.

Fig. 19.

is considerably less than it may be after some contemplated extensions are put in. The equipment readily lends itself to this condition. The tanks may be installed large enough for future use and only sufficient plates burned in to meet the original demand. As the load increases, more plates can be added until the tanks are full. No other change is required. This spreads the initial cost over a considerable period of time and, consequently, lightens the interest charges. Fig. 18 shows this condition of battery.

It is, of course, well, in installing a battery in this manner, to put in wiring of sufficient size to carry the current which the battery will discharge at its fullest maximum capacity. This also applies to the instruments on the switchboard and to the booster if such a piece of apparatus is used. It is sometimes possible to

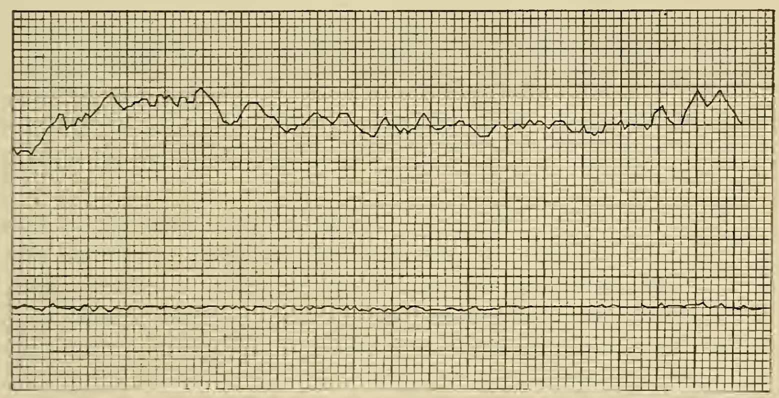


FIG. 20. VOLTAGE CURVES IN A STATION BEFORE AND AFTER INSTALLING ELECTRIC BATTERIES.

so design this latter machine that it will be capable of carrying considerable overloads for short periods of time; and, where the installation is to be used on fluctuating work, a booster so designed and installed, where the tanks are only partially filled in the first place, will often suffice for the enlarged battery; provided, however, that the heavy discharges made possible by the extra plates do not last longer than the overload rating of the machine. In street railway work and central station work this practice of installing larger tanks than is necessary for the first needs of the battery has become almost universal, and it is rather the exception to see a battery installed at its full capacity when it is contracted for.

There is another use in factory work to which storage batteries are very extensively put; that is, in the manufacture of incan-

descent lamps. Throughout Ohio generally, and also in Cleveland, we have factories turning out high-grade incandescent lamps which depend absolutely on storage batteries for all power used in adjusting, rating and testing their lamps. It is a well-known fact that an incandescent lamp, burning up to candle power on a 110-volt circuit, will vary almost one candle power per volt of variation in the current supply. It is, therefore, evident how necessary it is that the pressure should be absolutely constant. No generator can supply a current of this steadiness, and for this reason the use of storage batteries has become practically universal in this line of work. The filaments are also adjusted by passing electric current through them, and it is necessary that the current should be cut off immediately upon the point being reached where the filament has the correct resistance. Ohm's law tells us that current, resistance and voltage are all interdependent on any system, and, in order that this may work properly and automatically, it is again necessary that no variation in current should be felt at the lamp. Figs. 19 and 20 show the effect of a battery in regulating the voltage on a system which had previously been run without it.

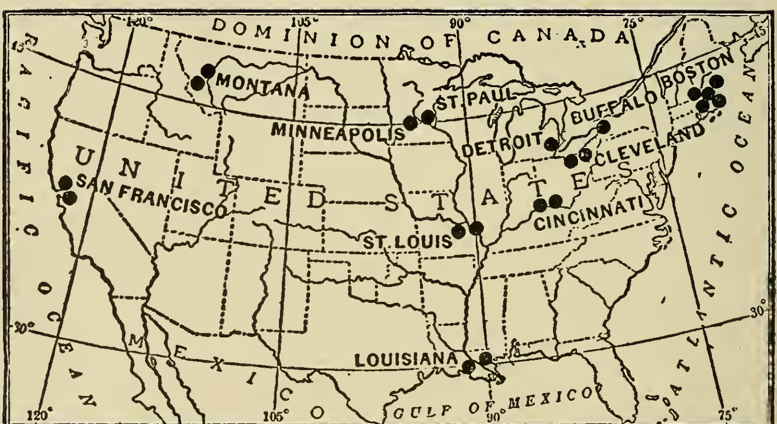
There are many other uses to which storage batteries are put in mills and factories, in the way of operating telephone exchanges, call bells, fire alarms, special electrical machinery, etc., but these are more individual than general in their nature and cannot very well be taken up in a paper of this scope. The main use to which batteries are put is, of course, in assisting the generating plant along one of the lines above outlined, and it is here that we must seek for the benefits which it is capable of bestowing.

Lack of space requires that mill and factory batteries should generally be installed in tiers, whereas central station and railway batteries may almost invariably be placed in a single layer, owing to the fact that the larger size of the battery generally necessitates a special building.

In closing, it seems desirable to mention one other point on which a battery may be of great assistance to a factory, and that is when used in conjunction with a gas engine. Considerable complaint has been made by users of this kind of prime mover that the results obtained were not satisfactory, owing to the intermittent effect of the explosions, which was very apt to cause flickering of the lights, and also owing to occasional breakdowns, which, though perhaps easily remedied, were still of a sufficiently serious nature to cause delay in work. The battery not only vastly improves the electrical service which a gas engine is able to give,

but also regulates the general distribution from the plant and maintains a twenty-four-hour service, even though the engine is run but a comparatively short number of hours each day.

Such, then, are the main features of a battery installation as used in mills and factories. It is undoubtedly a fact that they require considerable care in the way of seeing that short circuits do not occur, that they are kept properly cleaned, properly charged and properly watered; but despite this fact, the advantages which they render, when installed in connection with electric plants, are so great that they are daily coming into greater use in this line of work. Whereas, heretofore, the storage battery business has been confined very largely to electric railway work and large central stations, we find to-day that numerous isolated plants are going in all over the country, in the borough of Manhattan, in New York city, there being some forty-one batteries of this type, representing thousands of kilowatt hours capacity. It is safe to assume that in time the storage battery will be considered as essential a part of any electrical equipment as is any other reservoir in plants where the load is intermittent.


DOMINION OF CANADA
UNITED STATES
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
GULF OF MEXICO
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
120°
105°
90°
75°
30°

ASSOCIATION OF ENGINEERING SOCIETIES.

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STREET RAILWAYS.

A SERIES OF PAPERS READ BEFORE THE BOSTON SOCIETY OF CIVIL ENGINEERS, MAY 14, 1902.*

I.—The Street Railway System of Providence, Rhode Island, and Vicinity.

BY GEORGE B. FRANCIS, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

CHARACTERISTICS.

The street railway system of Providence and vicinity was first operated in 1865.

There are 270 miles of track, 743 cars, 2100 employes, and in 1901 there were about 54,000,000 passengers carried.

On January 1, 1900, there were 175 miles of track. Since then there has been built 64 miles of track and purchased 31 miles of track, making a total now of 270 miles of track.

About eighteen miles of this trackage is on private right of way and was formerly owned and operated by steam railroad companies.

This trackage is located in eighteen different cities and towns in Rhode Island and Massachusetts.

There are four operating companies (so far as accounts are concerned), all operated by the same officers and all controlled by the United Traction and Electric Company of New Jersey. The names of the four operating companies are as follows:

The Union Railroad Company.

The Pawtucket Street Railway Company.

The Rhode Island Suburban Railway Company.

The Interstate Consolidated Street Railway Company.

*Manuscript received July 21, 1902.—Secretary, Ass'n of Eng. Socs.

The Union Railroad Company, as its name indicates, was originally made up of several small horse railroad companies in the city of Providence and the city of Pawtucket. Later it absorbed, by lease, the Providence Cable Tramway Company.

The Rhode Island Suburban Railway Company acquired the property of the Pawtuxet Valley Electric Railroad Company, the Cumberland Street Railroad Company, the Barrington, Warren and Bristol Company and the Warwick and Oakland Beach branch of the N. Y., N. H. and H. R. R. Co.

The Interstate Consolidated Street Railway Company's lines are made up of still earlier companies operating between Pawtucket, R. I., and Attleboro, Mass., and North Attleboro, and the Attleboro Branch Railroad, a part of the N. Y., N. H. and H. R. R.

As these various companies lap over in the different cities and towns, it is necessary, in reporting the mileage, for various purposes, to divide the report into twenty-nine main divisions, representing each company in each city or town. These reports embrace two other grand divisions, one of renewals and the other of additions; and each of these is again sub-divided into (1), main tracks; (2), turnouts and crossovers, and (3), car-house tracks.

The Railroad Commissioner also requires the mileage of *road-bed* independently of track mileage.

The reporting of this mileage for assessors, franchise taxes, bond purposes and car mileage annually, quarterly and monthly is one of the most trying and puzzling duties the engineer has to perform.

There are not less than twenty-seven kinds of rail in the main tracks, to say nothing of the variety of guard rails, etc., in the special work.

The improvements, existing and contemplated, in track and underway, are,

First. Placing of concrete beams under the rail and the avoiding of ties altogether in some instances.

Second. The placing of at least a foot of gravel ballast under the ties in all track, instead of using whatever material happens to be convenient.

Third. The decrease in spacing of ties to possibly 22 inches, C to C.

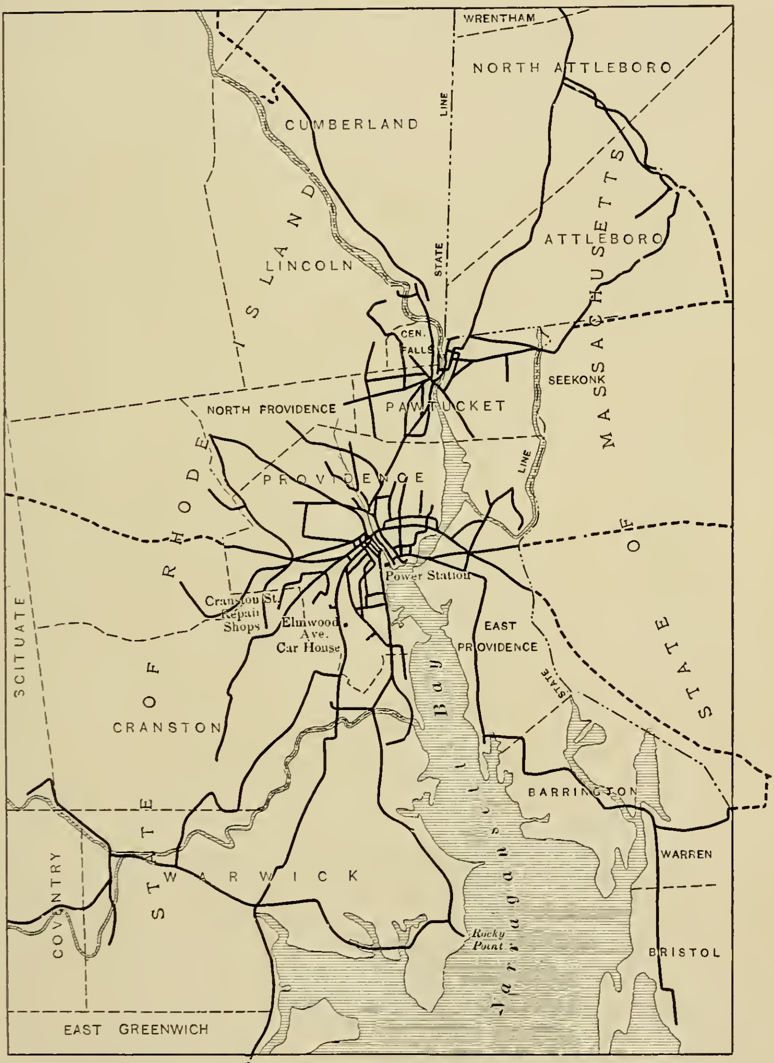
Fourth. The increase in width and length of ties to not less than 7-inch widths and 8-foot lengths.

Fifth. The placing of guard rails on all curves of less than 600 feet radius.

Sixth. The placing of switch tongue on the opposite side

from usual practice, in a good many cases, so that main track will be free from the tongue.

Seventh. The adoption of a lock for switch points as soon as a suitable method can be found for the various conditions.



DIAGRAMS SHOWING LINES OPERATED BY THE UNITED TRACTION AND ELECTRIC CO.

Eighth. To locate interurban lines, as far as possible, on private right of way, so that control may be had over grades,

alignments, drainage and all features of the track, as well as speed of the cars.

Ninth. To avoid sharp curvature and reverses in curvature as far as possible.*

Tenth. To improve the usual country bridges, so that there shall be no chances taken as to the sufficiency of their strength, even though it requires expenditure on the part of the railroad to bring about this condition.

Eleventh. To improve the private bridge floors so that they shall be brought up to the standard reached by steam railroads, namely: close tie spacing, guard rails, guard timbers, and all carried well back onto the ground.

Twelfth. To eliminate the mate, so called, wherever possible, and use double-point switches connected together, thrown by a stand and capable of being locked.

The type of rail to be used is still dependent on the location of the track, whether in the city or in the country.

Some of the peculiarities of street railroading which impress the steam railroad engineer are as follows:

First. The greater cost of street track per mile, under city conditions.

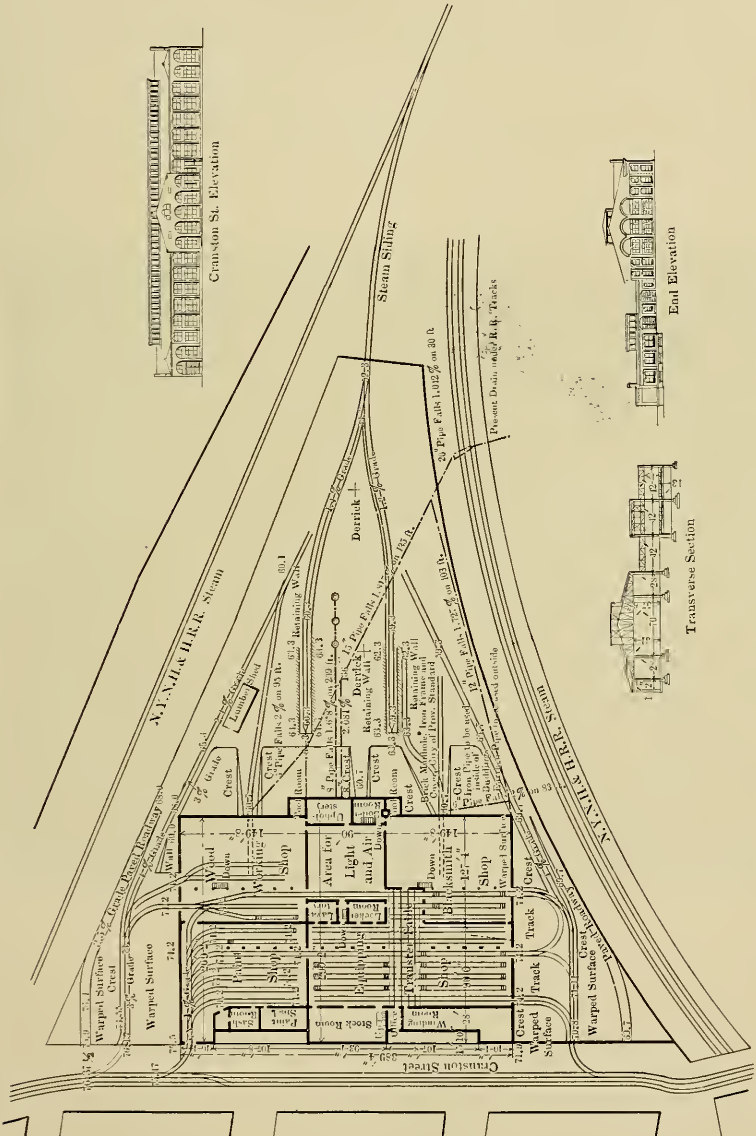
Second. The fact that, under the charter of the Rhode Island Suburban Railway, the tracks are laid under the direction of about thirty-five different highway surveyors, who are more or less changed every year, thus having about thirty-five unpaid, inexperienced chief engineers who must not under any circumstances be roiled with any contention. In some instances the ideas of these town officers are at total variance, so that what is insisted on in one town is positively prohibited in another.

The drainage of the track is usually sacrificed to the drainage of the roadway.

In some instances no definite location could be obtained until the tracks were laid, and then quite likely the location was changed in part after the surveyor could see how it looked. The same with grades. In one town grades were prescribed by the town officer, and, after the tracks were laid, the raising and lowering of track was insisted on.

*It is a broad-minded municipal engineer who does not strive to make the street railway track secondary to all other features of street traffic, and again and again municipal engineers utterly ignore the fact that the railway is primarily for the convenience of the public, as against the profit of a monopoly. Some public officials, as well as many individuals, are utterly unable to look beyond the ownership of the railroad, to the convenience of the people who ride in the cars, and this is true even of some who ride.

In a great many cases no street lines existed, either by record or by fences. When it came to the location of turnouts it was nearly impossible to get the town officer to realize the relations of



RHODE ISLAND SUBURBAN RAILWAY CO. CRANSTON STREET REPAIR SHOPS, GROUND PLAN AND TRACK LAYOUT.

speed, time and distance. In some cases the locations which would be approved for turnouts were stated, utterly regardless of the needs, and it was with great difficulty that the turnouts were at last placed somewhere within reason.

On one of the lines three turnouts were placed opposite convenient cemeteries as the places where the least objection would be made to their location, but opposition was made by the authorities that such locations would disturb funerals.

Advantage was always taken by the town officers of the opportunity to obtain benefits in the way of regrading and widening roads, improving drainage, bridges and culverts. In one instance the town engineer resurrected a map of a road layout made in 1803, to oblige the street railway to fill in a bog which the town had dodged for ninety-seven years.

Cranston Street Repair Shops, Lavatory.

Third. Elevation of outer rail. Street conditions sometimes require a depression instead of an elevation. There are two peculiarities about derailments. One is that nearly all occur after dark; another that they occur on curves, and mostly on curves of fairly good radii, say 200, 300 or 400 feet, which are unguarded, and where the motorman thinks he can run at a good speed compared with sharp curves.

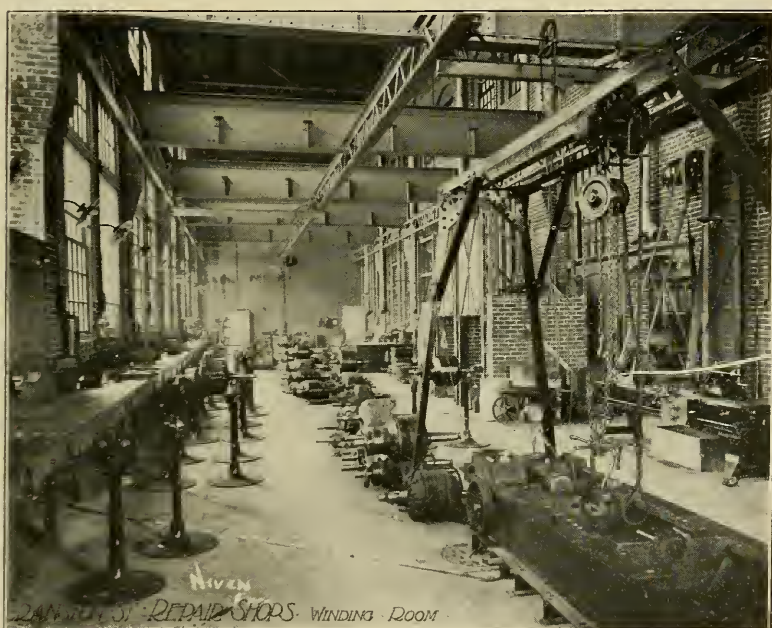
Fourth. Loose switch points. Nothing of this kind is found in steam railroading, and it will be a relief to street railroad men

when a reasonable method is found to fasten the points while they are run over.

Fifth. That such a reasonable and simple method will be found I am fully convinced.

We have now under construction such an attachment to the points, and, after giving it a trial, it will be described if found feasible.

Sixth. The grade crossing of steam railroads by street railroads. There exist about twenty such crossings in the vicinity of



Cranston Street Repair Shops. Winding Room.

Providence, and it is hard work to put up arguments in favor of any additional ones.

Seventh. The small flanges on street-car wheels and the trouble had with chipped flanges due to running over special work.

It has become the custom in street railroad construction to build the special work in such a way that when the wheels pass through the mates and the frogs they shall bear on the flanges, thus avoiding the pounding over the break in the head of the rail, the consequent noise and the severe wear on the switches and frogs. With light horse cars running in the cities only, and at low speed, this practice may have been defensible; with heavy

cars, which must first go through the city streets at moderate speeds and later run upon the suburban and interurban tracks at high speeds, even reaching forty or more miles per hour, it seems to me that it is wholly indefensible.

The flange of the wheel can never be made suitable to sustain the heavy car (unless made of steel, the cost of which is almost prohibitive, it being as 5 to 1), as its necessary form, namely: a fairly sharp edge of a circle, precludes it. At present the chipping of these flanges is a very serious matter, and it is going on so extensively that no railroad manager can hope to keep up the removal

Cranston Street Repair Shops. Iron-working Shop.

of wheels as fast as required by this cause. The result is that many cars are being run at high speeds, with flanges very badly chipped for a larger part of the circumference of the wheels, and the value of the remaining part of the flange is not in proportion to its depth, as it is so jagged and scalloped by the breaks that on the least provocation the wheel climbs the head of the rail.

The principal reason for building the special work in this form has been to prolong the life of the switch work. This is now being done at the expense of the life of the wheels and perhaps the lives of the passengers. It is only a question of time when the life of the

special work will be of secondary importance, and some other way will have to be found to accomplish the result desired. The only way which now comes to mind is the widening of the treads of the wheels from the present widths of $2\frac{1}{4}$ or $2\frac{1}{2}$ inches to 3 inches or more, so that, by reason of this additional width, the wheel may still bear on one portion of the frogs or mates until it laps over the space and begins to bear on the other portion. This is the reason why steam railroad wheels do not drop into the frog openings, and it can be applied to street railroads. This remedy again involves

Cranston Street Repair Shops. Paint Shop.

more care in paving outside of the rails, so that the wheel will not have to run upon paving obstruction. I know that the abandonment of the custom of running on the flanges will meet with opposition at once by railroad managers and special work manufacturers, but the perpetuaton of the practice has no foundation in common sense under the new conditions. That is to say, the chilled iron flange is not and cannot be made fit to do the work of the tread of the wheel.

In the Providence system the tracks pass over about one hundred and thirty-five bridges, forty of which belong to the street

railroad, the remaining ninety-five being public bridges, eighteen of which the street railway has been obliged to strengthen.

A bridge record book is kept, so that periodical inspections are recorded, as well as notes of all alterations, repairs and renewals.

The following is from an ordinance of the City Council of Providence regarding the size and weight of cars:

Maximum length, 42 feet.

Maximum width, 9 feet.

Maximum weight, empty, 42,000 pounds.

Maximum weight, loaded, 60,000 pounds.

Cranston Street Repair Shops. View of South and East Sides.

Some of the cars run quite up to these limits, and, in the case of some of the older double-track locations, it has been found quite necessary to widen out the distance from center to center of tracks, the standards being 11 feet on private right of way, 10 feet on streets where width of streets will permit, and 9½ feet for a minimum.

On the tracks formerly operated by the steam railroad, the freight service is moved the same as formerly—by means of motor cars. The passenger stations, some with and some without agents, are retained. On these tracks the steam railroad wheels and the

street railroad wheels go through the same frogs and switches. Special spring frogs are used, so that the narrow-tread wheels will not drop into the throats of the frogs. A speed of 40 miles an hour is obtained by the passenger cars on these tracks.

There are no transfers as yet, but on July 10 the law recently passed, requiring transfer tickets at all junction points, goes into effect. There are 143 of these junction points.

A freight and express service has been in existence for more than a year and is proving very useful. There are four track con-

Cranston Street Repair Shops. Paint-mixing Room.

nections with the steam railroad and seven with other street railroads.

There are about seventy-five buildings in this system, as follows:

Thirty passenger and freight buildings.

Sixteen car houses.

Five power houses.

Two shop buildings and twenty-two other and smaller buildings.

Seven of the largest car houses have just been equipped, at considerable cost, with the Grinnell Sprinkler System of piping to reduce the fire risk and insurance premiums.

The three buildings, the first two of which have been completed, about which I wish to speak more particularly, and which have been designed by the Engineering Department, are the new Elmwood Car House, the Cranston Street Repair Shops and the Manchester Street Power Station, the latter now under construction.

The new Elmwood Car House is a brick building, 200 feet wide and 360 feet long, containing fourteen tracks and capable of holding about 150 cars. It is divided into four parts by longitudinal fire walls and is lighted through the roof by saw-tooth skylights, the latter upon the recommendation of fire insurance experts. I disapprove this kind of skylight on account of its expense.

The pit rooms have granolithic floors, both between the tracks and in the pits. The roof is equipped with sprinklers and the pit rooms and other service rooms are heated with steam heat.

On this lot there is also room to double the capacity of the building. The illustrations exhibit the general characteristics. The cost of this building was 7.4 cents per cubic foot, with a total expenditure of about $175,000.

The Cranston Street Repair Shops cover about three acres of ground, and the road department yard, in connection with it, several more acres.

These shops are of brick and steel construction, with granolithic floors. They have a hot-air heating system and are equipped with sprinklers, and all the machinery is operated by electricity supplied from the main power station. The cost of this building and equipment is nearly $400,000. The cost of the building, with heat and light, has been 9.2 cents per cubic foot.

The power station now under construction covers an area of about 200 by 150 feet and is built on about 5000 piles, from 50 to 60 feet long, which passed through about 40 feet of mud and filling to a reasonably good bottom.

These piles are capped with 4 feet of Portland cement concrete and surrounded by a sheet pile cofferdam made of 6-inch splined hard pine in 40-foot lengths.

The superstructure is of brick and steel and is about 75 feet high. The boiler room supports coal pockets of 2500 tons capacity. The eight Babcock & Wilson 500 horse power water tube boilers will be equipped with Roney mechanical stokers and mechanical draught coal-conveying machinery will also be installed.

The engine room will contain two 1500 K. W. alternating current generators, one 1500 K. W. and one 1250 K. W. direct current generators.

The portion of the building now under construction is only one-half of that contemplated, and it is the intention, when the whole is completed, to abandon some of the present temporary stations and eventually the present main station.

This design was described in the *Street Railway Journal* for March, 1902, and the Elmwood Car House in the issue of April, 1902.

The contract cost of this building, including foundations, is 10.6 cents per cubic foot, with a total cost of about $900,000 for the entire plant.

Other items of interest concerning this railway system are the pensions for superannuated employes and the Employes' Mutual Aid Association.

DISCUSSION.

Mr. Henry Manley.—In view of the very much larger loads that are carried on railroads now than formerly, and also of the larger weight of the locomotives, is there any tendency to increase the standard gauge in this country?

Mr. Francis.—I think not.

Mr. G. R. Hardy.—Is there any reason, looking at the thing practically, why 4 feet 8½ inches is more desirable than any other; that is, a gauge about 4 feet that gives the convenience of a middle aisle and a two-seated seat on each side?

Mr. Francis.—The main thing seems to be that the gauge be uniform rather than 4 feet 8½ inches or 4 feet 9 inches.

Mr. Hardy.—The question I wish to ask is whether the seating capacity would be better if a change were made. You are acquainted with street railway work and you find your cars are better adapted to service if they have an opportunity to seat two persons on each side of the aisle. Will any other gauge do that as well?

Mr. Francis.—On the excursion to-day you rode on a car 9 feet wide over all, gauge 4 feet 8½ inches, with seats on each side, each seat accommodating two persons. The seat was somewhat cramped and perhaps you noticed it. The steam railroad cars are practically all 10 feet wide, some very little less and a few a very little more. The seats accommodating two persons are quite comfortable. Wider cars would give a little more room, but it is certain you could not seat three on each side. In my opinion a gauge of 4 feet 8½ inches, with 10-foot cars, furnishes good accommodation for a double seat on each side of the aisle.

Mr. Desmond Fitzgerald.—Is there any tendency in Rhode Island, as there has been in Massachusetts, to ask street railway

companies to pay for widening streets where that has been necessary?

Mr. Francis.—It is quite universally attempted.

Mr. Fitzgerald.—It has not been carried out?

Mr. Francis.—In some instances, it has.

Mr. Fitzgerald.—Is there any effort in Rhode Island to tax street railways?

Mr. Francis.—The street railway in the city of Providence pays the regular assessed tax. It also takes care of the streets between tracks and 18 inches outside; and it not only takes care of them, but furnishes the paving. It cannot go into a street and take up the paving and replace it. When it goes into a street the city carts away the paving and the company has to provide new. It also pays to the City Treasurer a large franchise tax over and above the regular assessed tax and the care of the streets. This franchise tax is based upon the gross earnings.

Mr. Fitzgerald.—Is there any law in the State of Rhode Island regarding the widening of streets and who pays for them? Is there anything definite about that?

Mr. Francis.—Nothing, when streets are widened for street railway purposes only.

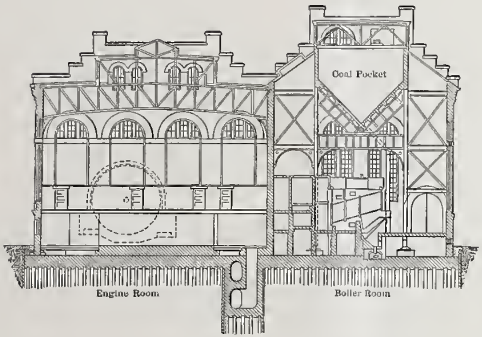
Mr. Fitzgerald.—Then, they have the right to impose the cost of widening streets upon the street railway?

Mr. Francis.—Not without the consent of the company.

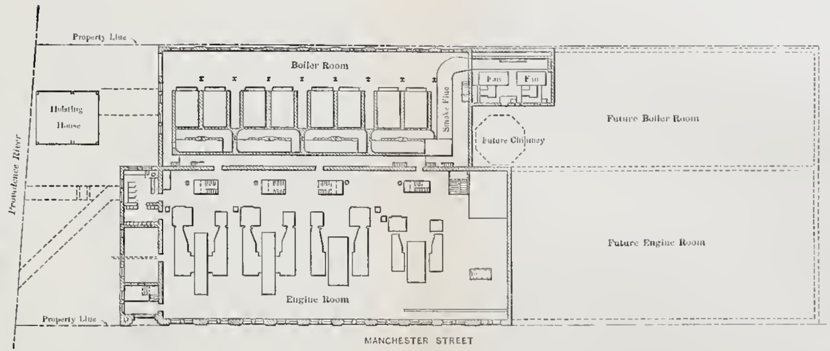
Mr. Fitzgerald.—Then they have a right to say to the company, "You can't have the franchise unless you do"?

Mr. Francis.—They can say so.

Mr. Francis stated, in answer to a question whether he ever had tracks laid on concrete, that they had been so laid where streets were asphalted on concrete. We have put down a longitudinal concrete beam under the rail and then concrete up to the asphalt, or within 2 inches of the surface. He also stated, in answer to the further question whether, under these circumstances they would stone pave around the rail, that they had put in scoria blocks, but that they did so no longer. When there is a longitudinal support the stone paving is unnecessary.



SECTIONAL ELEVATION.



PLAN.

RHODE ISLAND SUBURBAN RAILWAY CO. MANCHESTER STREET POWER HOUSE

II.—Street Railway Track Construction in City Streets.

By Arthur L. Plimpton, Member Boston Society of Civil Engineers.

I shall not attempt to discuss street railway track construction in general, but shall confine myself almost wholly to the track construction of the Boston Elevated Railway Company's system.

I will not take up time by describing the various changes which have taken place in the form of track construction from the days of the horse car, but will simply call attention to the various sections of rail that have been used since that time, as shown on Plates I and II. Before the days of electric cars, the tracks in the city of Boston and its suburbs were built either of tee rail (see Plate I, Fig. 7), laid on the side of the road without pavement, or of tram rail, as it is called (see Plate I, Figs. 3 and 4), which was laid on stringer timber of sufficient height to allow paving with granite blocks. Another form, known as the center-bearing rail, is shown by Figs. 1 and 2 on Plate I. This was used largely in the tracks in South Boston. These sections were called stringer rails and were fastened by spikes through the thin or tram part of the rail to the wooden stringer on which they were laid. Of course, even with horse cars, these rails were not very satisfactory, as the heads of the spikes would in time wear off from the teaming traffic and the rails were constantly becoming loose. So, even before the introduction of electric cars, the ability to fasten the rail below the surface and do away with the constant loosening was found to be a necessity, and light sections of girder rail were coming into use quite generally. Some that were in use in the Boston tracks are shown on Plate I. Fig. 6 was known as the Richards rail, and Fig. 8 as the Barnes rail. With the introduction of electric cars it was found that the rail which had served fairly well for horse cars was entirely inadequate for the greater weights and increased speeds. The form of rail went through various changes. We tried an English rail (see Plate I, Fig. 9), which was laid by the original West End Street Railway Company out on Beacon street. Some of this still exists in the tracks. A gentleman who came here from Providence introduced what was known as the Providence girder rail (see Figs. 10 and 11). This rail was laid on concrete piers, which supported it every $7\frac{1}{2}$ feet, but they proved to be insufficient, and it became necessary, sooner or later, to go over the road and put in ties to support it in the old fashion. The failure was largely due

to the fact that the cars were turned onto the tracks before the concrete piers had had time to set.

Figs. 12 and 13, Plate I, show some of the early sections laid on the lines out to Roxbury just before the road was operated electrically. Figs. 14 and 16 show 6-inch girder sections with the corresponding guard sections. Fig. 3, Plate II, shows a section of rail used in reservations. This is a high tee rail, or a girder rail of the tee form, the height of which is necessary in order to permit loaming the track and to give a sufficient depth of loam over the ties.

When deep girder rails were first considered, the thought was that a rail which would extend from the head a sufficient depth to allow paving with granite blocks would be a very expensive form. The attempt was therefore made to get the necessary depth at the ties without having the rail more than 5 inches deep between them, and what was known as the welded rail was introduced (see Plate II, Fig. 1). This had a welded foot at each tie, but it was never used very extensively.

The next step was to use what is known as the 9-inch girder rail, which was laid with a plate and which I will describe later. This gave 10 inches above the ties, permitting the use of an 8-inch block with cushion of 2 inches of gravel between the block and the tie. This is our standard rail of to-day, with varying forms of head, as shown on Plate II, Figs. 4 and 5.

Fig. 6, Plate II, shows the 85-pound tee rail, with bolted guard, used in the subway track.

On Plate III, Fig. 1, is shown the standard track construction which has existed since the 9-inch rail was introduced. On top of the tie there is a plate of cast iron about $1\frac{1}{4}$ inches in thickness, so that, with the rail, which is a little less than 9 inches, we have a height of 10 inches. The plate has the added advantage of backing up the spikes and holding them against the base of the rail. The spacing of the holes is very carefully designed, so that it will have that effect and yet not cause the head of the spike to be knocked off in sending it home.

When the city first began to put in concrete foundations in the streets and applied it to the streets where the tracks existed, it was found that this form of track construction lent itself admirably to the new conditions, as the depth to the bottom of the tie, some 16 inches, agreed exactly with the depth to the bottom of the concrete, and no change in the track construction was necessary. It could hardly be improved to-day for that particular form of construction. On Washington street the tracks have been renewed

and the new rails laid on the same ties, which were found solidly bedded in the concrete. Our experience proves that there is absolutely no advantage in concreting under the tie. The track construction is bonded to the rest of the street by the tie being bedded in the concrete; but, of course, if there is any settlement of the street below it will all go together, and this would occur even if

PLATE III

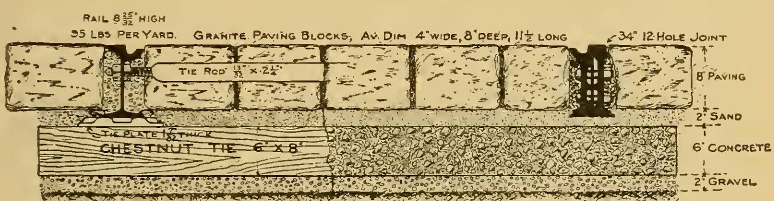


FIG. 1.
STANDARD "TEN-INCH" GIRDER RAIL CONSTRUCTION,—CONCRETE BASE.

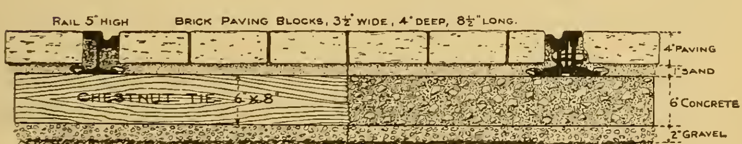


FIG. 2.
SUGGESTED SHALLOW CONSTRUCTION IN BRICK PAVING.

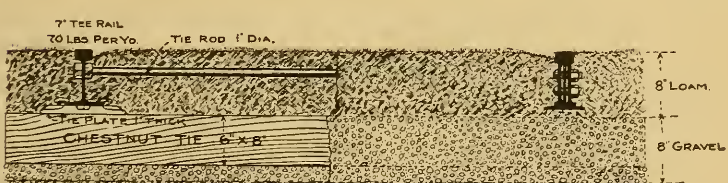


FIG. 3.
STANDARD TEE RAIL CONSTRUCTION IN RESERVATIONS.

there was a bed of concrete under the tie. The pavement in the track conforms in every way to the rest of the street, there being 2 inches of gravel here as elsewhere.

The tie rod, which is one of the most important parts of the track and which is required in order to hold it absolutely to gauge, particularly with these grooved rails, has been largely increased in size since the days of horse cars, it being now an inch in diameter at the threaded ends. We find that it not only stands the strains,

but allows something for rusting, so that it remains effective and lasts as long as the rest of the track.

A word or two about the joints. As shown in the section, there are two rows of bolts, twelve bolts to a joint. It is a fish-plate joint, the center of which is made to bear against the rail; and if that point should meet the web of the rail before the plates come to a proper bearing at the head and base of rail, the strain of the bolts would bring it to a bearing by bending the plate. It is designed to just touch there when plates are in their final position.

Mr. Francis having suggested, as one of the improvements in track construction, the laying of the rails directly on concrete beams, it may be interesting to state that I have on file in my office a drawing made by Thomas Doane, dated January 3, 1887, which shows that form of construction, which, I think, he adapted from methods used in England at that time. It was when he was connected with the original West End Street Railway Company, and he was evidently considering the use of this form in those lines in Brookline where the English rail was used, so that the idea of laying rails directly on a beam of concrete cannot be considered a new idea.

It is still an open question as to what is the best form of smooth pavement for a city street where there is a railroad track, and we have here in use on our system three different forms of smooth pavements, namely: asphalt, brick and wooden block pavement.

The form of track construction already described, which lent itself so admirably to the granite block pavement, is of much greater depth than is required for the asphalt pavement. There are 3 or 3½ inches of asphalt, and then 6 inches of concrete, so that, when certain streets were first laid in asphalt and it was applied to the track, it made all the concrete come above the tie, so that it was in no way bonded to the track construction. The result is the same in connection with a brick or wooden block pavement. It soon proved itself to be a very short-lived construction. In the interests of permanent construction, the railroad company decided to carry the concrete to a greater depth in the tracks than in the rest of the street, so that it would be flush with the bottom of the tie, thus bonding the track construction to the pavement; and this method has been followed during the last three years. This, of course, makes a very expensive construction. It gives a depth of 12 inches of solid concrete between the ties. It adds to the cost some $1100 or $1200 per mile; so that, if a number of miles of track were to be laid, it is obvious that a rail not over 5 inches in height, which

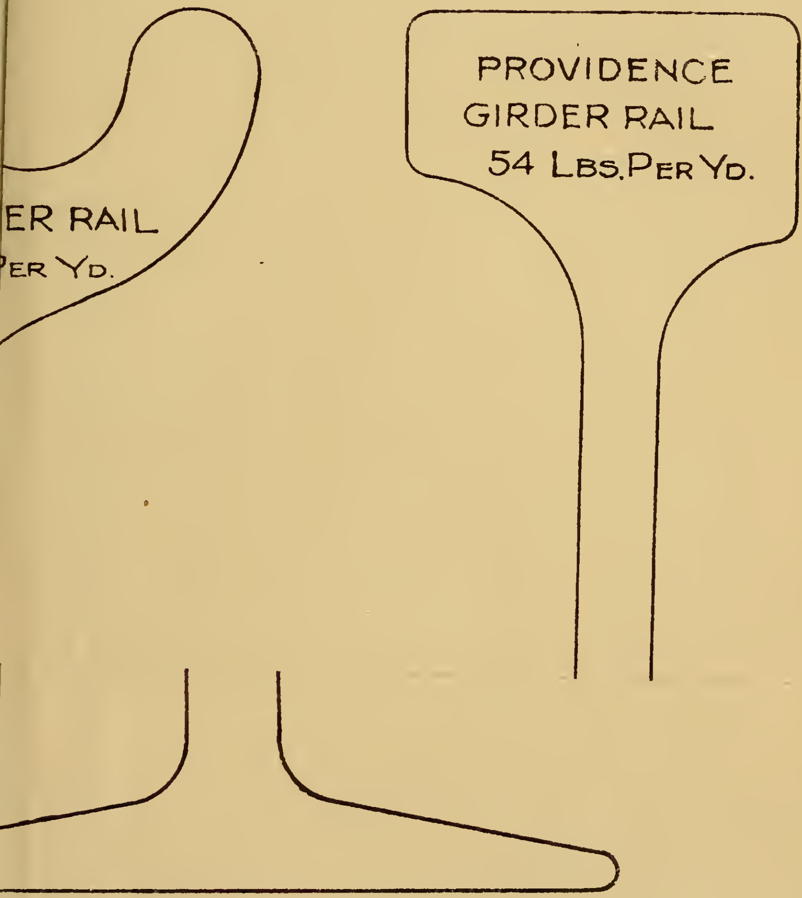


FIG. 16.

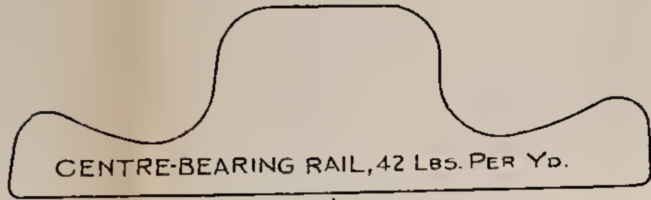


FIG. 1.

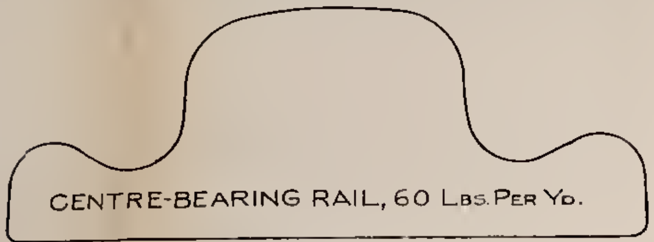


FIG. 2.

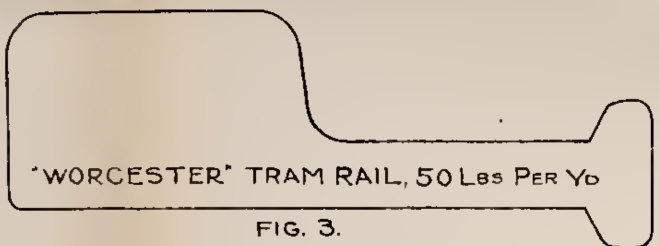


FIG. 3.

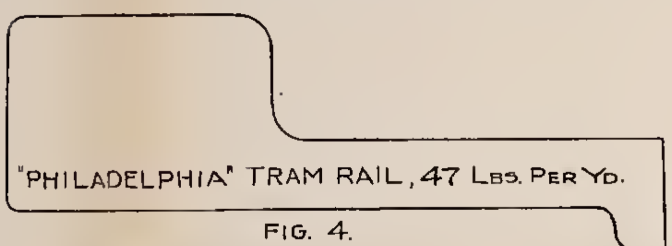


FIG. 4.

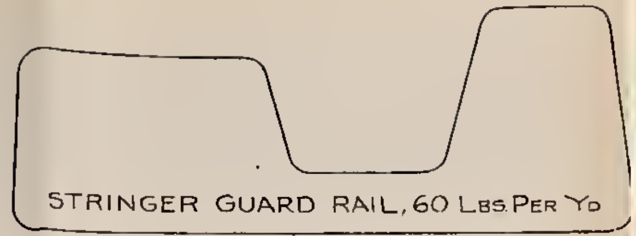


FIG. 5.

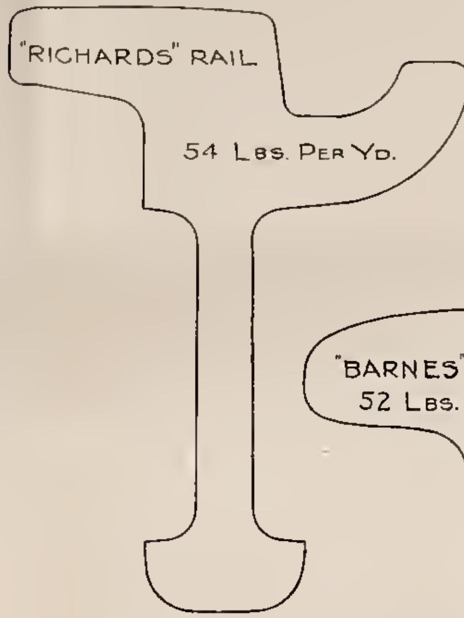


FIG. 6.

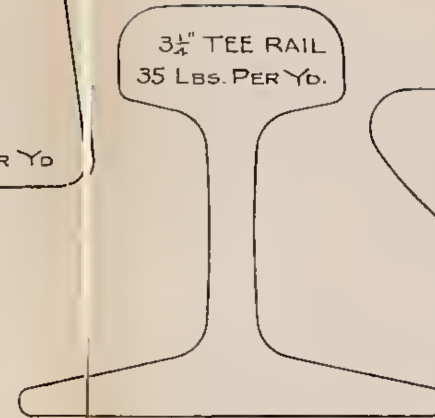


FIG. 7.

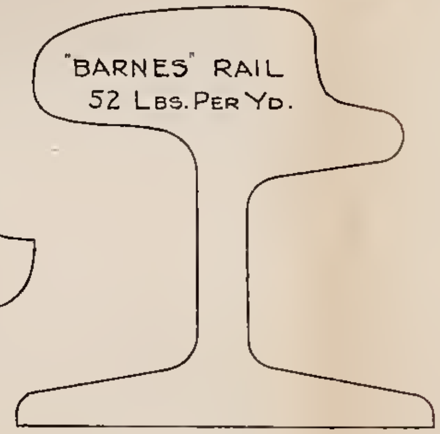


FIG. 8.

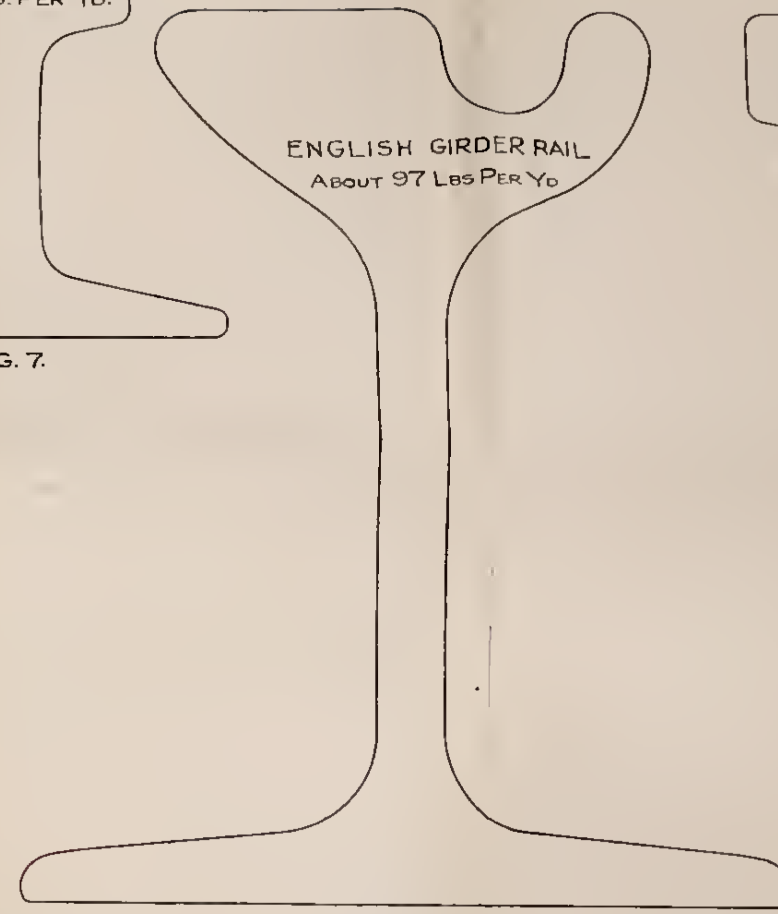


FIG 9.

FIG 10.

FIG. 11.

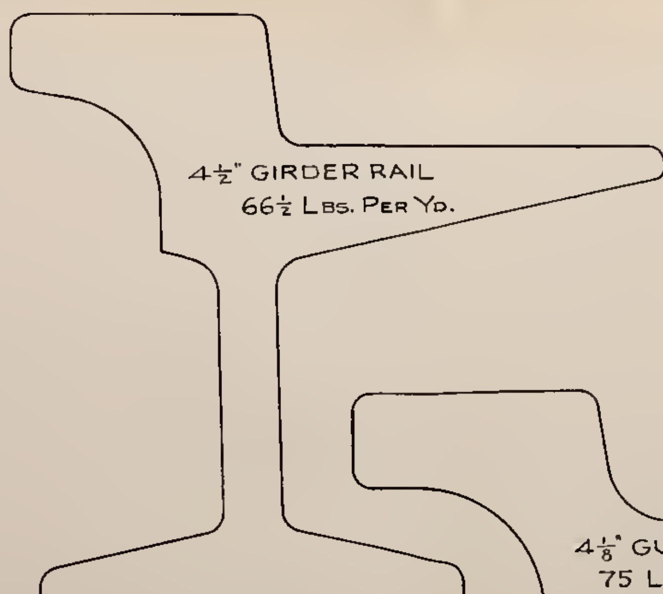


FIG. 12.

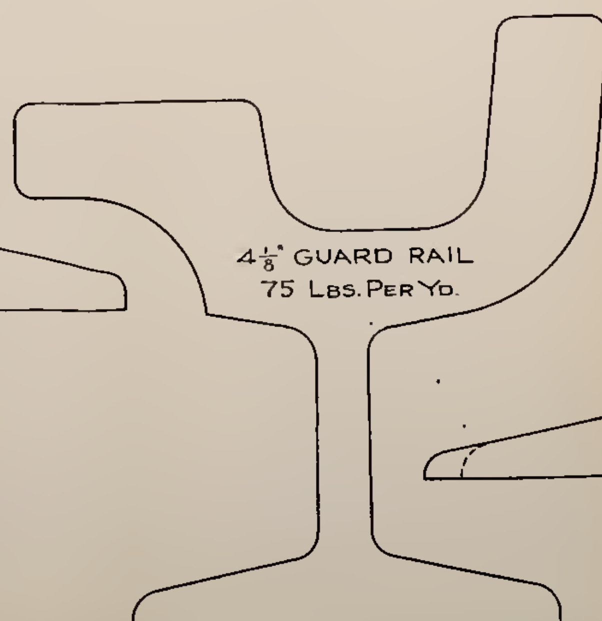


FIG 13.

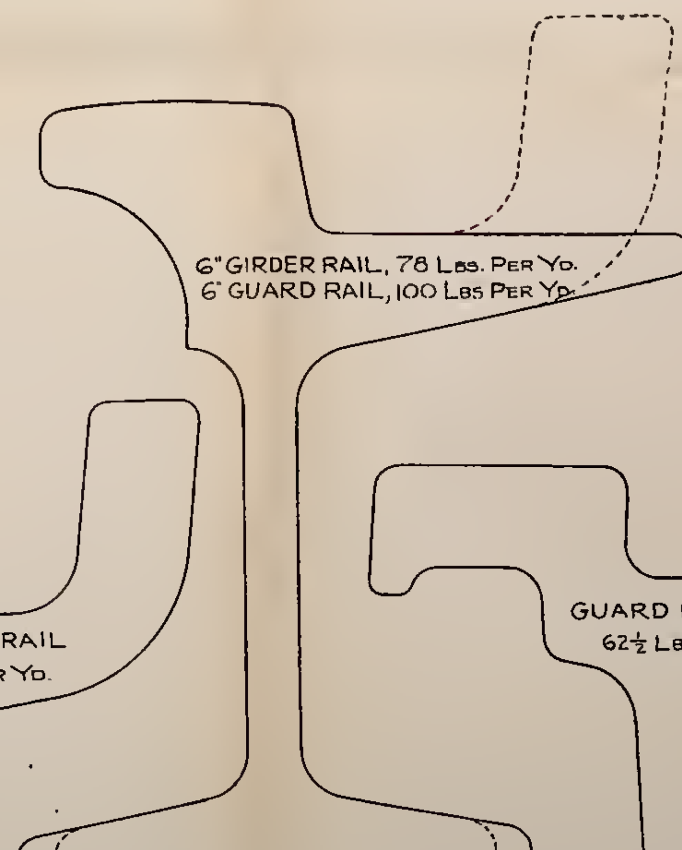


FIG. 14.

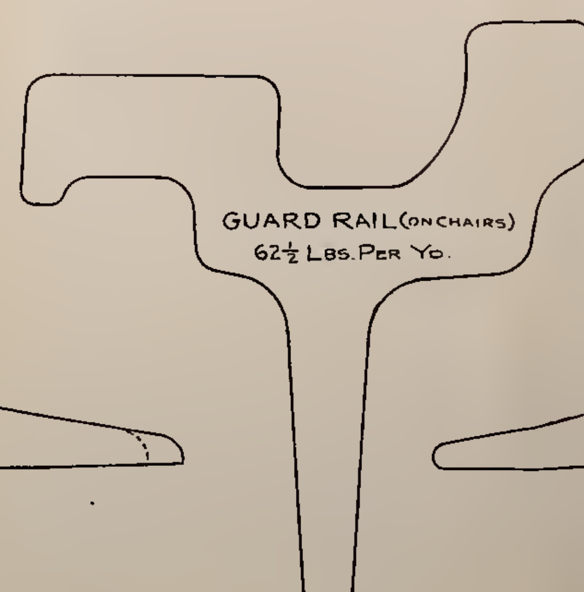


FIG. 15.

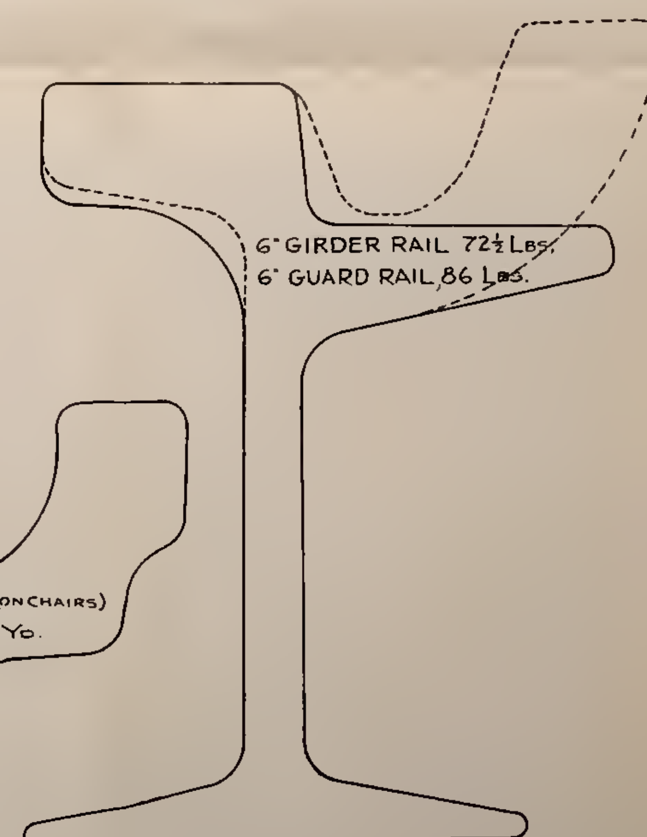


FIG. 16.

would bring the top of the tie up nearer to the top of the concrete, would give a much more economical construction. The depth of 9 inches for the rail was made necessary only by the depth of the granite block pavement.

This 10-inch construction, as we call it, laid with granite blocks on gravel base, costs, at present prices, about $18,500 per mile of track in a paved street where the city paves the roadway and the center between double tracks, the company paving the part that comes in each track. Similar pavement, laid with pitch and pebble joints on concrete foundations, costs about $23,400 per mile. The asphalted track proves to be the most expensive to build—about $26,600. The brick costs somewhat less than granite blocks—some $22,500.

I want to say a few words in regard to the difficulty of putting in a concrete foundation on a system like the Boston Elevated, where the cars are run the greater part of the twenty-four hours. In order to obtain as durable a construction as possible, cars have been run on a single track and not less than forty-eight hours given for the concrete to set; but in some cases it was absolutely impossible to do this, as the cars had to be run on both tracks early in the morning following the night when the concrete was laid. The concrete not having set, the tracks moved a little under the passing cars, so that the bond between track and concrete was broken. It seems to be unavoidable. It probably helps somewhat to pour in grout along the sides of the rails after the concrete has set. The only way to do perfect work would be to lay temporary tracks on the sides of the street; but in narrow streets, with a great deal of traffic, that is hardly practicable.

Even with the concrete carried up to within 3½ inches of the top of the rail, as is done in the case of asphalting of the street where there is considerable traffic, this proves to be a short-lived construction. The teams start a slight rut next the rail. This deepens as time goes on; and, although the tracks may be still bonded with the street, there will be a chipping and wearing away of the asphalt, necessitating repairs; so that, from the company's standpoint, a block pavement is preferable, and I think the different superintendents of streets have come to the conclusion that where there are tracks in the street and it is decided to asphalt the roadways, it is far better to pave the tracks and brows outside of them with granite blocks, filling the joints with pitch and pebbles, than it is to asphalt them. At first thought one would say that, from the standpoint of the driving public, the paving should all be asphalt; but an inspection of these streets laid with the combina-

tion pavement, when everything is covered with ice, would show that the driving public appreciates a roadway in the center of the street that horses can stand upon.

In the outlying tracks of the system where a reservation has been constructed in the roadway, another form of track construction has gradually been introduced which permits all pavement whatever to be dispensed with. It is considered desirable to make these reservations grass areas, and thus reduce the dust-bearing area of the street. At first it was thought that here was an opportunity to take up regular steam railroad construction, and a tee rail was laid in a number of cases in the earlier reservations, but that did not give a sufficient depth over the ties for the raising of grass, and a 7-inch section of tee rail has been finally adopted, laid on a 1-inch cast-iron plate, which gives a depth of 8 inches for loam over the ties (see Plate III, Fig. 3). This gives a much more elastic track, and the difference can be noted at once in passing from a solid-paved track onto a reservation track. Of course, the joint question almost takes care of itself. We have a joint with two rows of bolts and find there is little trouble in maintaining it.

Some years ago I spoke before this society on the cast welding of joints, which we were taking up at that time. There are some objections to the cast welding process, although quite a number of miles of track have been welded. The heating of the rails will frequently introduce a slight kink, so it has not been thought advisable to weld any new track, and in some cases it seems to soften or deteriorate the steel, so that it wears faster where the welds are made; and, although it largely reduces the number of joints to be taken care of, even if a certain percentage should break, yet this percentage is much larger than we would wish.

In the early days of electric welding several miles of track were welded here before the process had been perfected and many breaks resulted. I recently visited the city of Worcester, where at the present time they are carrying on the electric welding process, and it seems to have been perfected so that the results now are far different from what they were at first. The breakage, they state, is very small, indeed. The process is carried on in such a way that the head of the rail is not heated or its character changed; but it seems doubtful whether it will ever be practicable to take care of all the tracks in all the cities in this country in that manner. The necessary plant is very expensive, and the one at Worcester will be engaged there to the middle of the summer, I understand. A railroad can scarcely afford to own one for its own use; and, even if it could, in a busy time tracks are being constructed in half a dozen

or a dozen places at once, and means must be provided for joining the rails as the work proceeds. Furthermore, the track foreman should have it in his power to renew a worn or defective rail and put in the standard joint, which would be out of the question with any form of welding. So it seems the joint question has not been fully settled as yet. It seems to me that the coming joint will have the value of the present fish-plate joint, with a sufficient base support to hold the rail during the life of the rail. The joint used in the tracks in our subway seems to nearly fulfill all requirements. It is what is known as the continuous joint. It is a fish plate carried around and in under the rails, so as to provide, in addition, a base support.

Coincident with the changes which took place in the track construction, it was necessary to improve the form of construction of what we call special track work; that is, crossings or branch-offs consisting of switches and frogs. In the time of horse cars these were made of cast iron. Patterns were made in the shops and castings were made from them as wanted. Perhaps that sufficed for the lighter weights, but when the weights and the speed were increased they proved to be as inadequate as the early rail construction. The first improvement in the special work was to make it after the general idea of steam railroad frogs and switches; that is, they were made of rails cut to the desired lengths and angles and bolted together; so that the first improvement was the substitution of rolled steel in the place of cast iron. The trouble with this class of work was that, before it wore out, the action of the cars would loosen the fastenings; and, as we have not the same opportunity in a paved street of getting at these fastenings that they have on a steam railroad, the special work often became broken before the fastenings could be tightened, and was then beyond repair. The next thought of the railroad people and the manufacturers was to produce a solid frog. This was done in two ways: one by making the center of the frog a steel casting and then welding on the arms, while another manufacturer offered a frog which consisted of rails cast together by a mass of cast iron so designed as to give treads of rolled steel all through the frog.

Then we thought the question of special work was settled. Of course, anything new appears to be very nearly perfect until it begins to show its weak points. The defect that first appeared in this type of special work was the actual wearing out of the frog centers. Of course, the frog point presents only a narrow surface for the wheels to run on, and this gets double wear. The street railroad engineer said to the manufacturer: "You must give us

something better than rolled steel," and the manufacturer stated that he thought he was offering all that could be expected in producing rolled-steel frogs.

Very soon, however, a new form of frog, called a hardened center frog, was offered. This first form had a plate of Harveyized steel set into the center of the frog at the point of greatest wear. These centers of Harveyized steel proved to be far better than the rolled steel. Some of the plates showed signs of chipping, but the centers were made renewable, so that when one became worn, if the rest of the frog had sufficient life in it, a new one could be inserted. After using the Harveyized steel centers for a year or two, another type of construction appeared, in which the frog centers and the parts of the switches subjected to the greatest wear were made of manganese steel, and this is what we are still using.

Here are a few dates which may be of interest and which will show how fast these changes followed one another: The first girder special work was laid in 1889, then the welded special work which I spoke of followed along in 1892, and the guarantee center special work, which has the Harveyized steel centers, was laid in 1894. The manganese steel center work was laid in 1896, and up to the present time nothing better has been offered; so it would seem that, with the form of construction for plain track, shown on Plate III, with manganese center special work, the necessities in regard to track work for heavy electric cars have been brought practically to a point that it is difficult to improve upon.

Mr. Francis suggests certain improvements in track construction, most of which apply to a private right of way, with the exception, perhaps, of the use of concrete beams under the rail, which I have already alluded to.

In regard to the use of guard rails on curves, I will state that it has been the practice for some time on the Boston Elevated Road to place them on all curves of less than 1000 feet radius.

I can not agree with Mr. Francis in his suggestion to place the tongue on the long, or outer, rail of the curve. This would undoubtedly work all right with freight cars in city streets, with long-radius curves and with the deep flanges on the wheels; but under the ordinary conditions on street railroads there would be frequent derailments, as the effect of placing the mate on the short, or inner, side of the curve is like cutting out a length of the guard. In the usual arrangement the tongue serves as a guard through the switch.

I do agree with Mr. Francis that it is desirable, wherever possible, to use double-point switches connected together.

DISCUSSION.

Mr. F. W. Hodgdon.—I should like to ask Mr. Plimpton how long the rails will last?

Mr. Plimpton.—Of course, that depends very much on the locality in which they are laid. On a street like Washington street, between Boylston and Hanover streets, perhaps five or six years.

Mr. Hodgdon.—Then they have to be renewed. Do you find any improvement of late?

Mr. Plimpton.—I don't think rails wear any better now than formerly.

Mr. Desmond Fitzgerald.—You spoke about suburban rails 9 inches in height. They are laid direct on ties, are they not?

Mr. Plimpton.—Seven inches; that is, those that are laid in reservations. They are laid on a plate 1 inch thick.

Mr. Fitzgerald.—Is the track tied together in any way to keep it from spreading?

Mr. Plimpton.—There are tie rods five feet apart.

Question.—How does that track compare in durability with the other track?

Mr. Plimpton.—The trouble is with the ties, which, as a rule, rot out in a few years, on account of their being covered with loam, so that they have to be renewed before the rail is worn out. We have tried different forms of preservatives, and one that we have been using for three or four years past we hope will give added life to these reservation ties. It is bad construction from the railroad point of view to put loam on the ties. There is very little trouble from the rails or joints. It is a more elastic track, because the track yields under the passing car. Track laid in concrete has to take the full force of the blows from the wheels.

Question.—That form of construction must run very much better than $18,000?

Mr. Plimpton.—Yes, sir; I think it does. These figures, per mile of track, are for single track.

Mr. Hardy.—I believe tie rods are put in every five or seven feet. Do they ever fail?

Mr. Plimpton.—No, sir; we believe that the tie rod is all right. The lighter form did fail; and we have had to take them out of many miles of track, replacing them with the heavier rod.

Mr. Allen.—What is the size?

Mr. Plimpton.—$2\frac{1}{4}$ x 13-32 inches, with threaded ends 1 inch in diameter.

Question.—Do you ever use metal ties?

Mr. Plimpton.—We have used them, but very seldom.

Mr. Sidney Smith.—Can you give me any comparison of the life of the tie laid under a heavy rail, in one case bedded in concrete and in the other in gravel?

Mr. Plimpton.—The question of deterioration of ties does not concern us, as the ties will outlast the rail in anything except, perhaps, filled land; on original land the tie question is not a serious one at all in street railroad tracks. There is no trouble about securely holding the base of the rail. It is so far removed from the force of the blows that it is practically a fixture.

Mr. Smith.—Then it comes down to this: that, when renewal of the rail is necessary, it is necessary to remove the pavement and replace the ties? Or do you use the same ties?

Mr. Plimpton.—Yes; unless the rail wears out in a short time. The Washington street track was relaid on the same ties which were bedded in concrete. Of course, they had been in a very short time for ties.

Mr. H. V. Macksey.—Did I understand you to say that your company is now welding the joints in new track?

Mr. Plimpton.—We have never welded any joints on new track.

Mr. Macksey.—Do you weld the old track?

Mr. Plimpton.—Yes.

Mr. Macksey.—Do you still continue?

Mr. Plimpton.—We are not doing any this year.

Mr. Macksey.—Why on old track?

Mr. Plimpton.—The joints in the old track needed attention, and that seemed to be the best method that was offered of restoring them. In welding a joint you have the opportunity of wedging up a rail that has been forced down. It can be set up a little higher than the other rail; then, after it is welded, by the use of an emery wheel it can be ground off and made fairly smooth at that point.

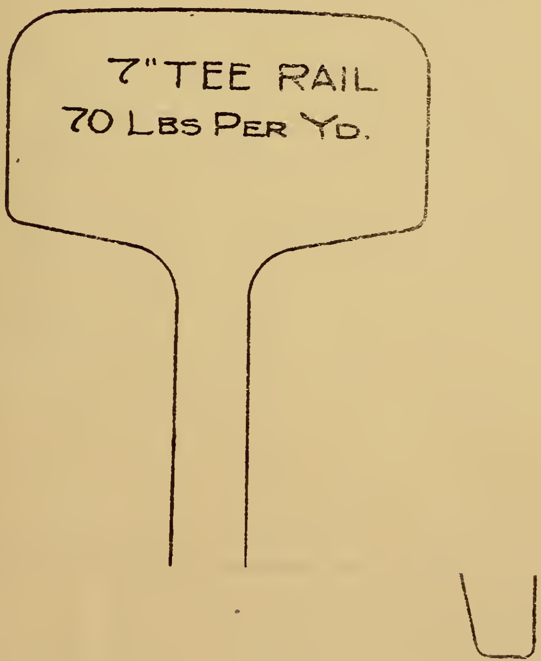
Mr. Macksey.—That still would probably be your custom as your present work goes on?

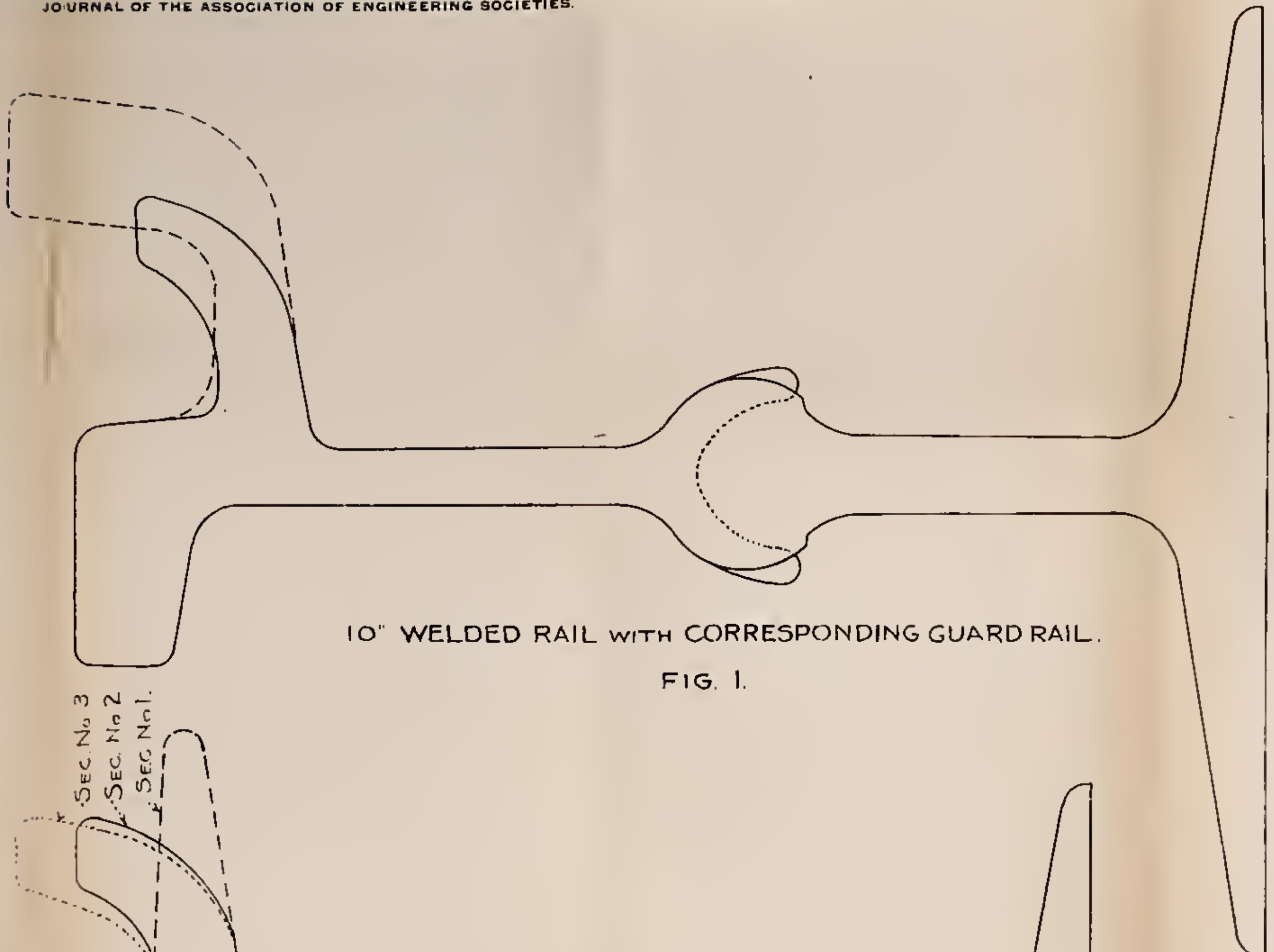
Mr. Plimpton.—Of course, we can't say. There are objections to the cast-welding process, and it would be impracticable for all railroads to get hold of the electric welding plants. There are only a few in existence, and they are very expensive plants.

Mr. A. H. Howland.—What load do you figure for bridge work?

Mr. Plimpton.—We figure that our heaviest cars, loaded, weigh twenty tons. That figure has been used in bridge calculations up to recently. The Railroad Commissioners now recommend that thirty and even forty tons be taken as the weight of a loaded car.

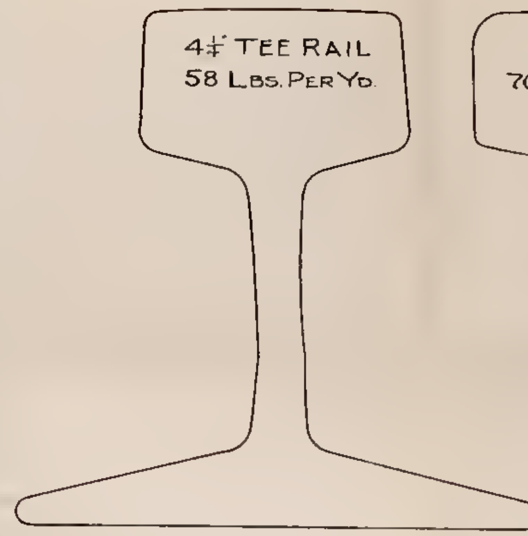
HUR L. PLIMPTON, STEEL RAILWAY TRACK. PLATE 2.





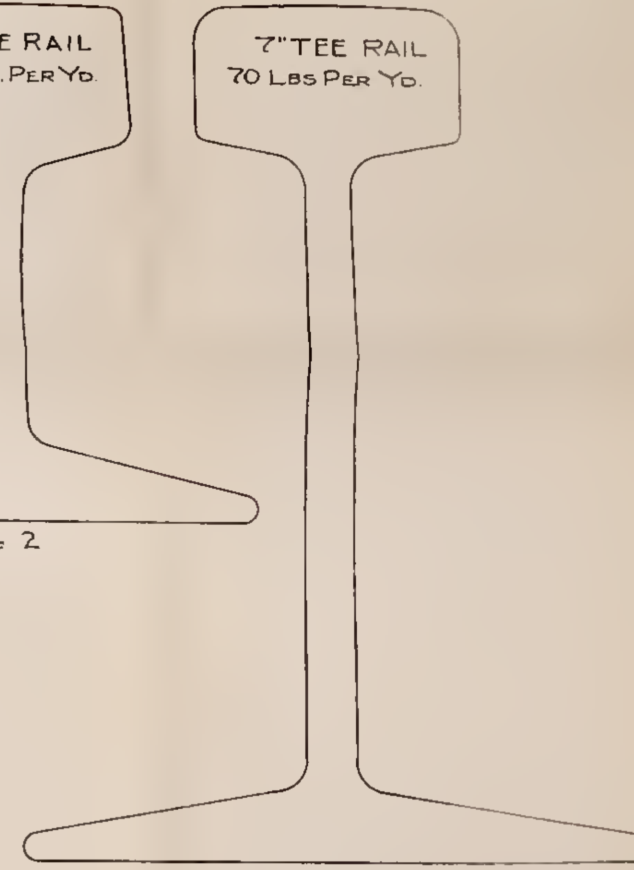
10" WELDED RAIL WITH CORRESPONDING GUARD RAIL.

FIG. 1.



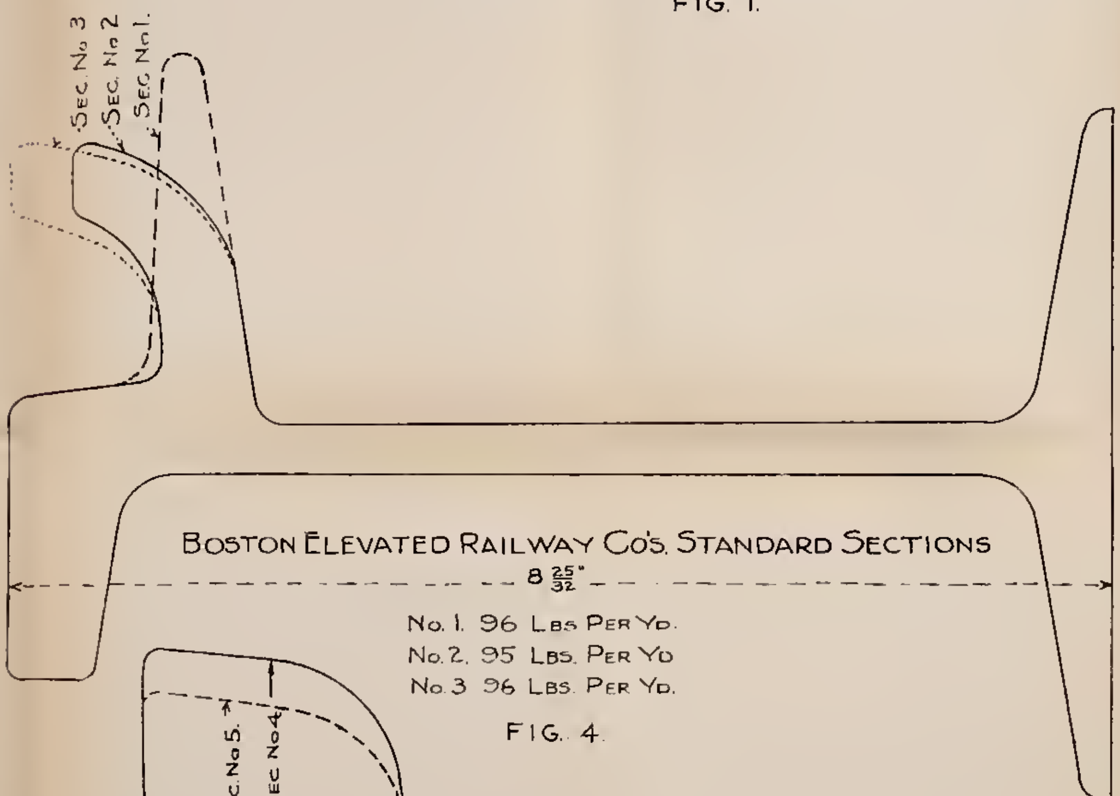
4¼" TEE RAIL
58 LBS. PER YD.

FIG 2.



7" TEE RAIL
70 LBS PER YD.

FIG 3.

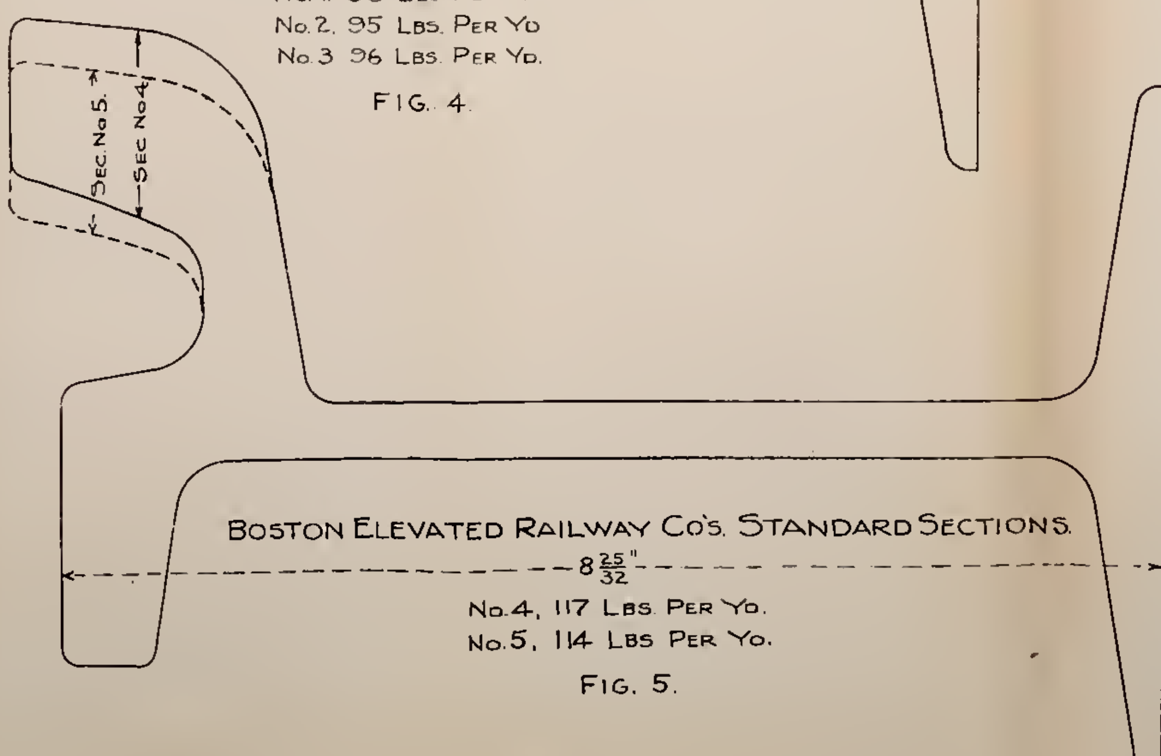


BOSTON ELEVATED RAILWAY CO'S. STANDARD SECTIONS

$8\frac{25}{32}$"

No. 1. 96 LBS PER YD.
No. 2. 95 LBS. PER YD
No. 3 96 LBS. PER YD.

FIG. 4.

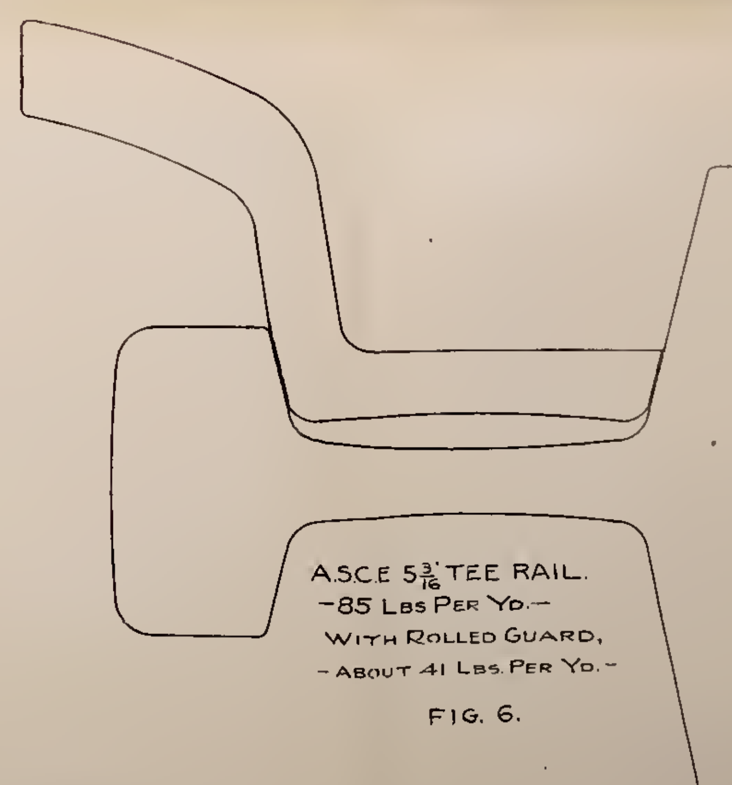


BOSTON ELEVATED RAILWAY CO'S. STANDARD SECTIONS.

$8\frac{25}{32}$"

No. 4, 117 LBS. PER YD.
No. 5, 114 LBS PER YD.

FIG. 5.



A.S.C.E $5\frac{3}{16}$" TEE RAIL.
-85 LBS PER YD.-
WITH ROLLED GUARD,
-ABOUT 41 LBS. PER YD.-

FIG. 6.

Mr. Francis.—Have you any of that Providence girder in Boston now?

Mr. Plimpton.—Yes.

Mr. Francis.—You spoke of it as originally laid on concrete. We still have about 20 miles in Providence, and you went over some of it to-day.

Mr. Plimpton.—It was originally placed on concrete piers $7\frac{1}{2}$ feet apart. They soon had to put ties under it, however.

Mr. Francis.—The cost of the rolled-steel, 9-inch rail approximates $43 or $44 per ton. With the high tee rail it is, perhaps, nearer $28. The grooved rail will probably wear out twice as quickly as the high tee rail. It probably costs three or four times as much for the grooved rail construction as for the high tee, if we could adapt it to street construction. Eventually, I think it will be adapted to street construction.

III.—The Relation of Street Railway Tracks to the Paving of City Streets.

By Mr. Henry Manley, Member Boston Society of Civil Engineers.

In the eye of those having the care of city streets, the rails of the street railway tracks are a nuisance; but, as they are permitted by the State, which is the owner of all streets when there is anything to give away, it becomes the duty of the officers of the city, with such co-operation of the railway companies as they may secure, to reduce and abate in part the nuisance which they cannot absolutely control.

The direct connection of the Engineering Department of the city of Boston with the street railway tracks began in 1891, at which time the Street Department called upon the engineers for assistance, and since that time substantially all new track work and renewals have been laid to grades furnished by the city. Previous to that time the railway engineers graded their own tracks and endeavored to fit the surface of the street as they best could, while maintaining a practicable grade upon which cars could run.

There was great lack of co-operation between the city and the railway; and when one corporation desired to reconstruct a street surface, the other was seldom ready, and the result was that the rails were fitted to the street, and later the street fitted to the rails, and as each work settled more or less, after the round had been repeated times enough, the tracks in the middle of the street were frequently found to be lower than the gutters. Latterly, the city and the railroad have worked more in harmony, but in rearranging the surface of the streets it has not infrequently been necessary to raise the tracks a foot or fifteen inches.

The form of the head of the rail used is a very important matter to the street surface. The desirable features are: As narrow a head as feasible, with the necessary groove or slot for the flange of the wheel made as narrow as may be, so as to keep wide tires out of it altogether, and of such shape as to enable a narrow-tired wheel to turn out of it easily without a wrench. The sides of the rail on each side of the groove should be of equal height, so that the pavement may be smooth.

The standard rail used in Boston does not absolutely conform to this specification, but is a compromise between the tram rail (which has no groove at all and has a difference in height of about

an inch and a quarter between the two levels) and the full-grooved rail with the sides of equal height. The difference in height of the two sides of the Boston standard rail is about ½ inch. The full-grooved rail is very extensively used, however, both in this country and in Europe.

The next point in which the tracks affect the maintenance of the street surface is the stability of the track structure. In this matter it has been necessary for the street railway engineer to make a radical departure from the practice of the steam railway engineer. Instead of purposely building an elastic track, the street railway engineer reverts to the primitive idea in tracks and builds a solid and immovable structure. In a well-built track the rail is so deep and the ties so near together that there is no perceptible spring to the rail, and the more solidly and firmly the ties are imbedded in concrete, instead of the loose ballast of the steam track, the longer and better do the rails and ties wear. It is left to the springs of the cars to furnish the desired elasticity. It is apparent that a street in which this kind of track has been built can be surfaced with almost any paving material without much fear of a dissolution of continuity between the track and the rest of the street; but no form of pavement will stand up in contact with an elastic track, and the attempt to find a pavement that will do so, or to persuade different kinds of pavement to do so, has caused endless trouble.

It is the general practice to lay a narrow brow of stone blocks outside the rails in all asphalt pavement, and either to do the same on each side of the rail or to pave all the space from out to out of rails with granite blocks or bricks. It must be remembered that the asphalt part of an asphalt pavement is only a carpet, and is very friable. It is very likely to fray out next the rail, even when the tracks are solidly built. It does just the same when laid against the stone block brow, perhaps not quite so quickly or generally; but by so doing the weak spot has been removed from the area of pavement for which the railroad corporation can be held responsible.

The street railway tracks interfere with the surface drainage of streets built on side hills or on irregular ground, for the reason that nothing short of a flood will cross the track. In a few places drain inlets have been placed between the rails and in a few other places the rails have been furnished with openings at the bottom of the groove, thus providing outlets which have been connected with drains.

Substantially all the railway tracks in Boston are paved. In macadam streets, where the ties are not imbedded in concrete, it

is necessary to lay a strip of pavement, usually stone blocks, outside each track, wide enough to cover the ends of the ties and to form a bridge or connecting link between the tracks and the macadam. A double track, with this paved strip or brow, occupies about 18 feet in width. The minimum width for a paved gutter is about 3 feet, or 6 feet for both gutters, making 24 feet in all. A street 60 feet wide has a roadway, between curbs, of 40 feet. If a double railway track runs through it, there will be left two strips of macadam, each 8 feet wide. Even this is too narrow a strip to maintain at average expense, and any street less than 60 feet wide must be paved with something beside macadam from curb to curb; not because it is desired, but because of the street railway.

The cost of repairs of any street of moderate width carrying railway tracks is increased, first, by the concentration of the traffic, as teams avoid the tracks; and still more markedly by the formation of ruts and grooves caused by teams moving in parallel lines and all in one direction on each narrow strip of pavement. The extra cost of these repairs is somewhat a matter of conjecture, but it is probable that the cost of maintenance in macadam streets is at least doubled by the presence of the tracks.

IV.—Track and Overhead System for an Interurban Electric Railway.

By Gilbert Hodges, Member Boston Society of Civil Engineers.

ROADBED AND TRACK.

A modern first-class and fully up-to-date interurban electric railway should have a location that will admit of the most direct route with as few curves as possible, and so laid out as to grades as to have them as easy as possible. In arriving at this condition, it has been found not only desirable, but most economical to purchase private rights of way, make heavy cuts and embankments and build costly bridges and culverts. The cross-section of the roadbed at subgrade should give a full and sufficient shoulder, beyond the ends of the ties, of not less than 4 feet on each side. There should be provided suitable drainage or culverts under the track wherever water is liable to accumulate to prevent washouts.

All bridges should be well designed by a competent engineer, and made strong enough to carry a car weighing 40 tons on a 17-foot wheel base, with a sufficient factor of safety to avoid material tax upon any portion of the structure. If the bridges are to be of wood, they should have short spans of from 12 to 16 feet, and where several spans are required they would naturally have either pile or timber trestle bents. All timber, entering into the framing of a bridge should be of long leaf Southern pine of the best grade to be obtained in the market, well framed and thoroughly fastened in every way.

Where piles are used they should be of upland white oak, if possible to obtain it. Red oak, chestnut oak and chestnut do not make satisfactory or durable piles. No piles grown in swampy or low lying soils should be allowed, as they will generally be found to have a coarse spongy wood which is sensitive to moisture and liable to early decay. Great care must be used in the driving of piles, to see that they not only reach a firm foundation, but also that they are not split or broomed at the small end by injudicious hammering. This work should always be done under the inspection of a competent engineer. Where steel bridges are used, they should be either of eye beams, plate girders, riveted trusses or pin and link trusses. Eye beams of proper size and number may be used with safety and economy for spans as high as 30 feet. Plate girders from 30 to 100 feet. Riveted trusses from 100 to 200 feet. For all spans over 200 feet in length the best practice is to use the pin

and link truss. All bridge floors should have ties not less than ten feet long and spaced not farther apart than eight inches in the clear. On the outer ends of these ties there should be a guard stick, gained down between the ties and securely bolted to every third or fourth tie. The office of these guard sticks is not, as is generally supposed, to prevent a derailed car leaving the bridge, for the stick is generally so placed that, should the car go so far as to reach it, the tendency would be for the car to topple over the side, regardless of this slight obstruction. The guard stick is intended to serve as a spacer for the ties, and to keep them in place longitudinally so that they shall not bunch up. Hence the importance of having the guard sticks gained down not less than an inch on the ties. For the purpose of keeping a derailed car from leaving the bridge, a heavy rail should be placed inside each track rail spaced about 8 inches away from it, and securely spiked and fastened to the ties. These rails, if properly spaced, will permit of a car dropping between them and the track rail, and will generally keep the car in that position, thus carrying it along in the direction of the track and preventing its leaving the bridge or striking the trusses. Guard rails should extend for a distance of not less than 60 feet from each end of the bridge, and then be brought to a point at the center of the track. No bridge, however small, should be without a protection of this kind. Assuming that the roadbed has been carefully graded and brought to subgrade, and the drains, culverts and bridges built, we then come to the work of track laying.

On the subgrade, as prepared, are laid the ties, which should be not less than 6 inches by 6 inches and eight feet long, of good sound chestnut, if possible to obtain. Ties should be hewn rather than sawn, and should be straight and lie level and true on their beds. They should be spaced not more than 2 feet on centers. To these ties are spiked the rails, which should be of a good section of Tee rail, weighing not less than 60 pounds to the yard. Most interurban roads use 70 pounds, and some use 75 and even 80 pounds. These rails should be 30 feet in length, and should have an improved joint. such as the Continuous or the Weber joint. Joints need not be over 24 inches long if of either of the two kinds mentioned. Too long a joint is as detrimental to track as is too short a joint. These joints may be laid squarely across the track, or they may be staggered or broken, as desired.

The discussion on this question is still going on, and each side has many sponsors.

An allowance for contraction and expansion should be made at every joint, usually about $\frac{1}{8}$ inch for every 30-foot rail laid at

the average temperature. The spikes should be $5\frac{1}{2} \times 9/16$ inches, and of the best quality of tough material. There should be four spikes to each tie; those on the inside so driven that they do not come directly opposite those on the outside of the rail. Very careful and thorough driving is quite essential. In placing the joint plates in position, care should be taken that they have a good bearing upon the rail, the nuts screwed up on the outside and the whole joint made rigid and firm. Care should be taken to have gauge lines of the two rails coincide at all joints.

After the rails have been spiked to the ties to a true gauge, the ballast should be put in place. This ballast should consist of good clean sharp gravel or of broken stone of a suitable size, and should have a depth of 2 feet and extend for at least 2 feet beyond the ends of the ties. In bringing the track to its proper surface and alignment, shovel tamping may be allowed, but no shovel tamping should ever be allowed on finished work. After the track has been thoroughly tamped, the ballast should be rounded off on the sides, and the entire roadbed left in a neat and smooth condition.

When the track has been made secure in true line and surface, the electrical connections may be made. All holes for electrical connection should be carefully drilled, and they should be reamed out or otherwise made bright and clean throughout their perimeter, immediately before the bond is applied. There should be two rail bonds, of not less than 4/0 capacity each, at every joint; and cross-bonds of the same capacity should be put in place, one in every 300 feet. These bonds should not be applied by hammer riveting, but should be put in place by pressure, either of screws or by hydraulic pressure, to insure the best possible contact. The track return, on electric railways, has so far not proved entirely satisfactory. Various attempts have been, and some are now being made, to discover a more practical and more reliable means of carrying the current by the joints, but so far it does not appear that any better means have been devised than that described herein; and therefore, with the knowledge that the best we have is not absolutely certain to keep up the voltage a long distance from the sources of power, it is evidently wise for us to use the best methods and best appliances that have so far been found.

All curves of 500 feet radius or less should be well guarded, not with another rail or other makeshift, but either by a bolted-on Z guard or by a rolled guard rail. On curves of very short radius, both rails should be guarded, and wherever it is possible all curves should be well elevated, to insure the safe and comfortable passage of cars at high speed. Curves of sharp radius should be either

compounded or laid with spiral or easement curves at their ends. The turnouts or side tracks for interurban roads should have split switches of the Lorenz or other similar pattern, with spring frogs, and their leads should be not less than 60 feet. Wherever the car houses are located, their switches, curves and connecting tracks should, if possible, lead out of a side track or turnout rather than out of the main line. Wherever cross-connections are used in double track lines, they should if possible be trailing cross-overs, so that cars running on their proper tracks would pass through the heel of the switch first.

The summing up of our remarks on track work will be, then: Prepare a good foundation; use large ties, close together; lay thereon good heavy rails; have plenty of good ballast, well put in place; make the best possible electrical connections and slight nothing; do not for one minute forget that good, substantial, well-laid track is a vital factor in the economical operation of a road and is a large factor in the earning capacity.

This is not imagination. The wisest railway operators are of this opinion, although a realization of its truth came very slowly, indeed, to some of them.

OVERHEAD SYSTEM.

Next to the track work, in the construction and equipping of an electric railway, comes the overhead system. In overhead construction the first item to be considered will naturally be that of poles. These should be of good sound chestnut, if possible to obtain, and unless otherwise restricted by local requirements. Hard pine poles are to be avoided wherever and whenever possible, as they are often very short lived and therefore very expensive to maintain, as well as being somewhat more costly at the outset. If square or hexagon poles are absolutely required, within the limits of cities or thickly settled villages, it will be found to be economical to obtain good-sized chestnut poles and have them sawed to shape, for they will have the longer life. We know of one urban road in this state, that now has large numbers of this kind of poles, and they have found them to be entirely satisfactory, so far as we have been informed. All chestnut or round poles designed for an interurban railway should be not less than 35 feet in length. They should finish not less than 7 inches in diameter at the small end, and should be no less than 10 inches in diameter 7 feet from the butt or large end, and they should be straight and sound. Hard pine poles, if used, should be of good sound long leaf Southern pine,

10 x 10 inches and 35 feet long, with tops not less than 7 x 7 inches. The poles should be fitted with two cross-arms, to provide properly for both direct and alternating current transmission wires as well as the necessary telephone and block signal circuits. These cross-arms should be of such sizes and so arranged as to meet the requirements, which will probably not be the same on any two roads. Generally it is thought well to have one two-pin arm above and one four-pin arm below. It is hardly necessary to say that cross-arms should be so placed as to come on opposite sides of adjacent poles, in order to form what is known as a storm line. Locust pins are used on straight lines, and iron pins or guard irons should be used on all curves or wherever any unusual strain is brought upon the pins. All poles should be well gained and roofed, and entirely stripped of bark before setting. They should be well set to a true line, and with sufficient rake to present a good appearance when the line work is finished. Poles should be 6 feet in the ground on straight lines, and at least 7 feet on curves. The earth or other filling should be well and thoroughly rammed around the pole, so that it will be firmly bedded and held solidly in place. No pole should be placed less than 5 feet from the nearest rail and no two poles should be further apart than 100 feet. Some interurban roads have cross-suspension or span wire construction throughout, on account of the heavy trolley wires and the correspondingly heavy overhead material. Where brackets are used, the flexible or Craighead type has been found to be the best. They should have extra heavy brace rods, and be not less than 9 feet long. They should be securely fastened to the poles at a uniform height from the rail. Spans should be made of seven-strand 5/16-inch wire, all guy wires of No. 4, and all anchor and pull-off wires of No. 6, best grade of galvanized wire, fastened to the poles by $\frac{5}{8}$-inch eye-bolts with 5-inch thread. It is considered good practice to have two trolley wires on long distance interurban roads. They are generally of large size, either 3/0 or 4/0, and of a grooved pattern. The wire should be hard drawn and of not less than 95 per cent. conductivity. They should be strung not less than 18 feet above the rail, and may be placed higher. Grooved trolley wires are supported by mechanical clips of brass or composition, of a length sufficient to produce an even surface for the wires. First-class hard rubber or compressed mica, surrounding the metallic portion of the hanger, is considered the best insulation. The very best overhead material that is made is none too good, and quality and durability, rather than price, should govern in the selection of all overhead material.

The feeder and return wires may be of copper or aluminum. The latter is very much lighter than copper. It is generally used at about 61 per cent. conductivity. At that value it weighs about half as much as copper of 95 per cent. conductivity, and, at present prices of copper, is about the same cost for wire, while a saving will be made in freight, cost of handling and labor of erection. It is strong and durable when in the form of a stranded cable, and has been proved for efficiency and economy. Where high tension or alternating transmission wires are to be put in place, they should have special insulators tested for the high voltage, of a good design and reliable manufacture. These high tension wires may be of No. 2 or No. 4 B. & S. gauge, and they are usually arranged for a three-phase system. This will, however, be governed by the types and the voltages of the instruments at the power station. All direct current feeders should be tapped to the trolley wire often enough to give good distribution to the current. This spacing of taps will be governed by the location of heavy grades and by the size and number of the trolley wires in use. The overhead system should be divided into sections convenient for the operation of the road, and, so far as possible, to obviate the crippling of the service in case of breakdowns, storms or other emergencies on the line. It is not necessary to paint the poles, nor has any form of preservation so far been used that has proved to be of much value for prevention of decay at the ground line. Painted poles, however, present a better appearance, and in villages and thickly settled districts they will be found to be desirable.

THIRD RAIL SYSTEM.

The third rail system has for a number of years been in use, both in Europe and in this country, but until recently has not been used much for surface roads. In order to have this system of practical value, it should be applied to such roads only as are largely outside of the highways and where the highway travel will not reach it. In other words, a road using this system should be located almost entirely on a private right of way. Of course this would not prevent any such road from using the highways at termini, or at important points en route where the overhead system would be necessary. There must, however, be long stretches of road where the third rail can be safely used, before it can be economical to put it in use.

When they were first brought into use, a hooded or yoke rail was used, of a special pattern costly to roll. This rail was put in place in the center, between two track rails, but it has been super-

seded by a tee rail on insulating blocks, placed either midway between the two track rails, or to one side of the track, according to the location of the contact brushes on the cars. The track construction, on a road of this type, should be about the same as, and ought to be fully up to the standard of, the road which we have just described. The overhead system will, of course, be done away with, and in its place a rail, having a low percentage of carbon, with the necessary joints, insulators, cables at crossings and other applications, must be put in place. When the third rail is located outside of the track rails, it has been placed about 26 inches away from the nearest rail, and it is elevated above the track rails in order to give good and sufficient insulation. For this purpose, extra long ties, about 9 feet 3 inches, are necessary, once in about every 10 feet. These ties should have sawn faces, and be of such wood as will hold bolts or lag screws. The insulators should, beside having the required insulating quality, also have strength to sustain the heavy third rail, which usually weighs about 80 pounds per yard. As already stated, this rail should be of a stated mixture of metal, and have an exceedingly low percentage of carbon, manganese and phosphorus.

It is the custom to provide, in the third rail, sufficient capacity to carry the entire current between sub-stations without any added feeders, and on this account the bonds at the joints must be of a capacity to carry this current, probably upward of 400,00 C.M. in most cases. These bonds can be applied to the bottoms of the rails, where they are out of the way and where a very satisfactory attachment can be made. Underground cables are used at highways and farm crossings to complete the circuit, on account of the rail being broken at those places.

In addition to a very careful fencing of the right of way, it will be necessary to construct cattle guards at all points where crossings or openings into the highway occur. There are at present, in New England and vicinity, but two roads which use the third rail outside of the Boston Elevated Railway, which, of course, is a purely city road and is not of the class now under consideration.

COST.

The cost of the roadbed, track and overhead system for interurban roads will vary, of course, according to the type of construction adopted, the character of the country through which it is located and the relative location and number of its power stations. For an example I will quote a road that is now approaching completion, and which is a good sample of the road which I have described.

The cost per mile, not including anything for equipment, power plant, buildings, etc., will be practically as follows:

COST OF ROADBED AND TRACK FOR ONE MILE.

14,300 cubic feet of earthwork at 45 cents	$6,435.00	
325 cubic yards rock work at $1.75	568.75	
Three acres of clearing and grubbing at $75	225.00	
3000 cubic yards of gravel ballast at 50 cents	1,500.00	
640 rods wire fencing at $1	640.00	
Pipe culverts	50.00	
Masonry for bridges and culverts	1,000.00	
Wooden and steel bridges	1,300.00	
Land for private right of way	1,000.00	
Total roadbed		$12,718.75

TRACK.

110 tons 70-lb. tee rails at $31.50	$3,465.00	
360 continuous rail joints at $1.54	554.40	
2640 6″ x 6″ x 8′ chestnut ties at 54 cents	1,425.60	
5870 lbs. spikes at 2¼ cents	132.07	
720 bonds in place at 61½ cents	442.80	
17 cross bonds at 50 cents in place	8.50	
Labor laying track	1,056.00	
Teaming material	270.00	
Total track		7,354.37
Superintendence and engineering		500.00
Total roadbed and track		$20,573.12

OVERHEAD SYSTEM FOR ONE MILE.

Poles, brackets, cross-arms, etc., in place	$650.00	
Trolley wires and overhead material in place	1,100.00	
Direct and alternating current feeders in place	1,750.00	
Block signal and telephone systems	2,000.00	
Superintendence and engineering	100.00	
Total overhead system		5,600.00
Total		$26,173.12

The foregoing figures include nothing for interest during construction. The construction of the roadbed and track for the third rail system, as applied to an interurban railway, will be found very nearly, if not quite as high, as the cost of a railway using the overhead system and on the same locations, when the cost of all the necessary additional safeguards is taken into consideration.

With reference to the general subject of the need of the best, most substantial and most carefully planned roadbed, track and overhead system for interurban roads, we wish to reiterate what we have before said as to its importance, its ultimate economy and

advisability from all practical points of view. When we consider that 40 miles per hour will be the possible speed of the cars upon a road now being built in Massachusetts, which is, we are informed, to adopt a schedule time of 20 miles per hour including all stops, and that we, ourselves, have ridden on a single track interurban road in Ohio at the rate of 60 miles per hour for 21 miles on a special trip, and that the schedule on that road calls for nearly 50 miles in places, it is evident that the money, carefully and judiciously spent to secure the very best construction in all parts of a property which goes to make up the way for the passage of the cars at these high rates of speed, is well spent, and that any scrimping or saving in this direction is not only poor economy, but is the most unwise policy that can be pursued. To those who have long advocated the building of roads in a substantial manner, who have on their part endeavored to see that roads under their supervision were so built, it is a source of satisfaction to see, at last, the owners and operators of railway properties fast coming into line and constructing their roads more and more in accordance with what is the best and most modern practice.

V.—Street Railways and State Highways.

By Harold Parker, Member Boston Society of Civil Engineers.

The Massachusetts Highway Commission was permanently organized upon a plan laid before Governor Russell by a preliminary committee appointed to investigate and report. A year of quite hard work of this committee resulted in an elaborate report and recommendations and a draft of a bill. This bill became the foundation of the highway laws of Massachusetts. From year to year certain changes or modifications of the original statutes have been made, but in the main the law stands as at first drawn. It is gratifying to know that since 1894 many of the other States have followed Massachusetts in respect to highways, and the Massachusetts laws and regulations are examined with the greatest care in preparation for similar legislation in other commonwealths.

The fundamental theory of Massachusetts highway policy and the aim of the Massachusetts Highway Commission is to establish a network of excellent roads, suited in each case to the traffic over them, connecting each town with its market, and thus ultimately creating continuous roads from city to city, from end to end of the State and with the adjoining States north, west and south. The Highway Commission does not, by any means, consider through roads (roads leading most directly from one large city to another) as the main object. It does, however, believe that these through roads will ultimately be the result of first uniting each town with its neighboring town, working out in radial lines from the centers of distribution through all adjacent villages and through them to those beyond. You will realize, upon a little consideration, that the same thing that creates the need for a street railway also makes a smooth, hard road not only to be desired, but a practical necessity—to wit, the assurance of the speediest, smoothest and most economical means of conveying yourself and your product to market and back again.

The difference between a State highway and a street railway, so far as its actual relation to the public is concerned, is that the latter is used for greater distances than the former. The average distance driven is not over five miles. For greater distances other means of conveyance than a horse and carriage will generally be employed. What I mean to call your attention to is that both State highways and street railways follow about the same general lines of travel, and that, although one conveys passengers to a greater

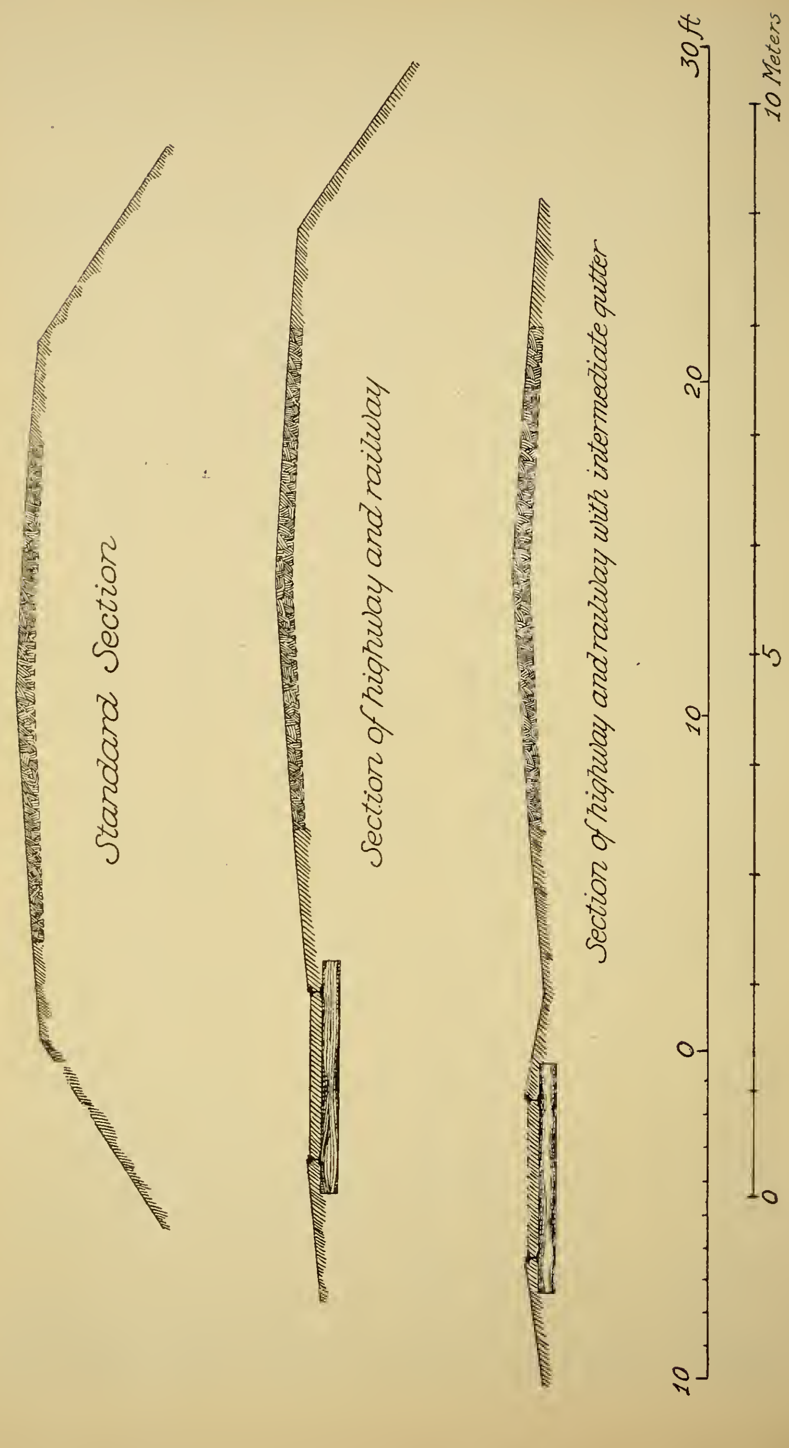
distance than the other, they both lead into the nearest and most important center of population. So it appears that, if a through line of either highway or street railway is developed, it must, from the nature of its evolution, pass through as many towns on the way as it can make available.

A few years ago no one would have ventured to predict the extraordinary growth of street railways; neither would one have predicted the State highway as it is; but that they have grown together and along the same lines shows the very strong public need which these two serve. The street railway law of 1898 gave to street railway franchises a permanent value which they did not previously possess; and this, added to their vast usefulness, has brought into their management and development a grade of men very much superior to those who put the early ones in motion. These men see very clearly the wisdom, not to say necessity, of giving the public the best service and at the same time securing the most stable track and the most smooth-running cars, with every possible improvement brought into use.

There is little doubt that up to the present time the street railway system of Massachusetts has been the best that has been produced anywhere in the world. I mean by "the best" that which gives the smoothest track, the most commodious cars, the greatest speed consistent with safety, the most satisfactory service and the longest ride for the money.

I have tried to indicate how these two great foundations for travel have grown in importance side by side. It follows, of course, that they must come into contact. The laws of the State give to the State Highway Commission all necessary authority to protect the public welfare, except that they do not give it the right to act in a judicial capacity. It can fix the location and grade of any street railway that proposes to come within the side lines of a State highway, or of any that already occupies a road subsequently laid out as a State highway, and it may apportion the cost of changing the grade or line. It may, also, upon petition of proper parties, establish line and grade for a street railway on any road that it may decide shall at some future time become a State highway, and may apportion the expense between the Highway Commission and the street railway company. It may determine the size and shape of the rail, the kind of surface, the place and method of crossing, the extension of culverts and bridges.

It being manifestly the duty of the Commission to take care of the public safety and convenience, no track can be laid within the limits of a State highway without a special decree showing the


Standard Section
Section of highway and railway
Section of highway and railway with intermediate gutter
30 ft
20
10
0
10
10 Meters
5
0

exact location of track and profile, with specifications in detail. Where a change of grade is necessary in cases where the street railway is already on the ground, the Commission carefully computes the share of expense that the railway company should pay, and the agreement between the two is made before the work begins.

The nearest rail is never allowed to be nearer than 4 feet from the edge of the macadam, and a greater distance is to be preferred. The Commission has usually required the street railway track to conform to the line of the cross-section, following the regular slope of $\frac{3}{4}$ inch to 1 foot. In practice, however, it has been found that this outline of cross-section is not always the best. Under these conditions water, in passing off the road surface, follows the rails, and in grades often does much damage. It also frequently happens that, in heavy soil in cold weather, the ground is heaved above the rail, and much inconvenience, not to say danger, results. Further than this, it does not seem quite the fair thing to turn all the water from the highway onto the street railway track, although the State, under the law, must maintain the whole. It seems to us that, under ordinary conditions, it is probably better to lay out a shallow depression or gutter between the shoulder of the highway and the end of the tie. It frequently happens that, for other reasons than these, it is better to elevate the track above the road. It is usual for the Commission to require the railway company to extend culverts or bridges similar in design to that used in the highway. Where it is necessary for a street railway to cross a highway, the grade line is accurately determined so as to cause as little depression in the highway as possible. The weight and section of rail and kind of surface to be used are specified in the decree. We have usually found that a brick surface between the rails, and 18 inches or more outside, are best. There is, of course, no end to the number of individual points of contact between street railway companies and the Highway Commission, but a consideration of these would be outside the scope of these remarks. Since I have been a member of the Commission there has hardly been an instance in which the street railway officials have not readily accepted our conditions, even where these involved them in considerable additional expense.

In concluding these remarks, which have been, of course, of a very superficial character, I wish to add that I believe the means of transportation, barring steam railroads, perhaps, are better in Massachusetts than elsewhere in the known world, and that the laws regulating them more thoroughly protect the passenger and secure his comfort and ease; and that, to a surprising degree, the

managers of street railways realize this and lend their aid to its accomplishment. It may be said that it is manifestly to the interests of these corporations to do this. Yet we should congratulate ourselves that their wisdom is great enough to see it. The duty of the Highway Commission is to preserve the equipoise of justice and reason, and to build good and useful roads.

President Kimball.—We have with us, this evening, Mr. Sergeant, Vice-President of the Boston Elevated Railway, and I will ask him to say a few words.

Mr. C. S. Sergeant.—Mr. President and Gentlemen: The hour is so late that I think the kindest thing I can do is to express my hearty thanks for the pleasure I have enjoyed in going on your trip this afternoon and in hearing the papers presented this evening.

I may, however, call attention to one point. Your speakers this evening have brought out two old conflicts—the conflict between the track construction and the car construction, and the conflict between that track construction which is best for cars and that which is best for vehicles—and those two irreconcilable conflicts have been going on ever since I have been connected with street railways, and I fear they will continue to go on.

In connection with the railways, there is coming in one new element that has to do with safety. The interurban car is coming here, and it is coming everywhere. That interurban car must travel at high speed; must have a broader tread and a deeper flange, and must come into the heart of the city. This requires some form of rail that will enable the car to run in the country and a form that will enable it to run in the city. This brings up a question which is looming up before street railway and highway engineers. The question of economy has never been permitted to count. Great expense to street railways in renewing tracks has resulted from the fact that wheel treads were so narrow that the tracks soon pounded out. They very quickly wore out the metal and came down on the flanges. Then we had to take out the rail and throw it away. The question of expense has never been permitted to regulate the form of rail; but when the question of safety of interurban passengers comes up, some compromise rail, which gives greater safety and longer life, will have to be adopted.

ROTATIVE PUMPING.

BY JOHN RICHARDS, M.E., MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, June 6, 1902.*]

THE most remarkable feature, in fact, in the implements of modern engineering is the change from reciprocating to rotative machines such as involve fluid action. It is so extensive and is moving so fast that one is led to doubt the old rule of "A Century of Evolution" for any noted change in engineering practice.

It required a full century to develop reciprocating steam engines; and it is only in the last decade that scientific men began to perceive the ultimate results that could be expected in these important machines, and there are doubtless present many people who have observed the whole of the final and rapid improvements during the last twenty years, which have been more and greater than during eighty years that preceded.

The latest phase, and most important of all, is the change from direct pressure or reciprocating engines to the impulsive or free-running type without steam-close bearing. Ten years or so ago, in a paper read before this Society, I had the temerity to enter upon some prophecy respecting this matter of impulsive or turbine steam engines, but am as much surprised as my fellow members at the extraordinary progress made in that direction and the fulfillment of that prophecy.

Such engines do not form a part of the present paper, and are mentioned here to illustrate analogous progress made in machines for impelling fluids and to point out how machinery for pumping fluids, both elastic and inelastic, is assimilating water wheels or machines for receiving and transmitting the force of the same fluids under pressure, and that we are now, as may be assumed, near a point when the laws that govern the action of such machines will become known and form a safe guide to their successful construction.

I will include in these preliminary remarks a quotation from a letter recently received from Mr. Charles Brown, C.E. of Basel, Switzerland, who, although retired from actual practice after an experience of nearly fifty years, gives much useful consideration to this subject of fluid machines.

The extract is as follows:

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*Manuscript received June 18, 1902.—Secretary, Ass'n of Eng. Socs.

With this century we have certainly entered an anti-reciprocating machinery epoch. The Parson's Turbo is working its way rapidly. The works of Messrs. Brown, Bouverie & Co., at Baden, Switzerland, and Mannheim, in Germany, are crowded with orders. Last year they began selling, and have placed some eight turbo-engines and dynamos of 150 to 5000 horse power. The consumption of steam is low, being 12 pounds of water per indicated horse power for the smaller sizes and down to 9½ pounds for larger sizes, distancing altogether reciprocating steam engines of the highest class, and, added to this economy of steam consumption, there is the saving in lubricating materials, and consequent grease-free condensed steam for supplying the boilers, which run for indefinite periods without scaling, so that a less number of stand-by or reserve boilers are required. There is also a great saving in the item of repairs, and they require very little looking after, one man sufficing for several engines.

Compare the above with the case of large reciprocating engines. The American Allis engines of the Glasgow electric street railways require for each engine some seven greasers to keep the multiplicity of organs properly supplied and cleaned, in addition to two engine tenders, or about nine men in all, a number sufficient to attend all the turbo-engines in existence if they were assembled in one place.

I hear it is decided to employ Parson's turbine engines for the 70 to 100,000-horse-power station for the unification of the London Metropolitan Railways. Mr. Parsons is now making direct-connected rotary fans to deliver air at a pressure of 25 pounds per inch.

Besides this extract, Mr. Brown's letter contains much news relating to European practice that is of equal interest, including some remarks upon the Rateau engines made in Paris, also respecting the De Laval system; and I might, if time and circumstances permitted, say something of recent practice in this city pointing to important advances in impulsive motive machines for both water and steam.

Reverting now to pumping apparatus for liquids of the rotary free-running or centrifugal type, it has been following its course of evolution, not regularly, but in a spasmodic way, since it took on a practical or commercial form in 1820 to 1830.

The energy of impellers can be exerted on either of the angles A E or C, in Fig. 2, or on any intermediate angle. Radial action, as on the line A, may result from centrifugal force or from impulsive force, owing to speed of revolution, the form of vanes or the velocity of the water, but the kinetic energy in the water can not be converted to pressure without water spaces arranged as in the Sulzer pumps, of which drawings are given. At the other angles, E and C, the resultant energy of flow, or tangential energy it is called, can be utilized inductively as in common centrifugal pumps, but at considerable loss owing to the differences of velocity.

This effect costs nothing in a constructive way except a volute form for the casing, which harmonizes to some extent the velocities of the impeller and the flowing water acted upon, which velocities vary from *four* to *one* to *ten* to *one* owing to the head or pressure.

The origin and history of mechanical invention is a matter of no practical importance, but is always of interest, and I will quote here from an article of my own, written in 1886, relating to the centrifugal type of pumps which until very recently have remained the most important of their class:

I presume each of the prominent nations in Europe considers the invention of centrifugal pumps as belonging to their people, and it was a matter of no concern until the method came to be extensively applied to useful purposes and took its place as a manufacture, but there is scarcely a doubt that the first organized centrifugal pump was invented by Denis Papin, about two hundred years ago, in Hesse, Germany, where it was called the "Hessian suck." This pump of the celebrated Frenchman, of which there are drawings in existence, was by no means a bad one, and in all essential features, except a volute casing, corresponded to the construction afterward adopted in this country in 1818 and continued with but little change.

The celebrated Dutch engineer, Huet, says that Perreboom introduced horizontal centrifugal pumps in Holland in the first years of the nineteenth century; but as no precise date or examples are named, some allowance can be made for Huet's evident prejudice against centrifugal pumping, because he instantly follows this remark with the statement that thirty years later Lipkens made his celebrated single-acting pumps for draining Haarlem Lake. Huet's work, "Stoombemaling Van Polders and en Boezems," 1885, gives scant mention of centrifugal pumping, although at that time such pumps might be said to have supplanted to a great extent the old cumbrous Dutch pumps in Holland, as elsewhere.

Another of the oldest drawings, extant at this time, is that of Le Demours, a Frenchman, dating from 1732. It is a kind of "Barker mill" machine, and the forerunner of various pumps on the same principle, that of Barker's mill inverted, which have been periodically invented ever since, one within the writer's knowledge a few years ago here in California. The same invention, or "mode of operating," is said to have been discovered in connection with reaction water wheels in their overrunning and drawing the water from the chute or inlet after the gates were shut.

Mr. Whitelaw, an inventor of reaction water wheels in their common or applied form, himself converted the method to pumping by centrifugal force and made pumps of the submerged type that gave some very good results, which were fortunately tabulated in a careful manner, in 1849, at Johnstone, near Glasgow. These tables contained factors for friction of both water and machinery, with exact measure of resistance and power, that would do credit to a scientific commission of our day. Whitelaw's pumps were first made about the year 1848.

A centrifugal pump of the type shown in Fig. 1 was made in Massachusetts in 1818, found its way to New York and in 1830

such pumps were exhibited there as a known invention. These pumps, as may be seen, embodied most of the features of common practice. From this followed a number of examples in this country of which we have sparse record down to 1851, when Mr. James Gwynne, who had made his past pumps in this country, began their introduction in England and established their manufacture there, which has continued very successfully ever since.

Centrifugal pumps are in many ways an attractive manufacture. They all operate with a reasonable degree of efficiency, admit of cheap, inaccurate fitting and are produced at a very low first cost; good enough for most purposes when the pressure is slight, but under higher pressures, or exceeding 50 pounds per inch of area, a purely centrifugal pump encounters various resistances that interfere with its efficiency.

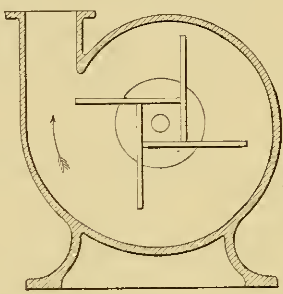


FIG. 1.
MASSACHUSETTS PUMP, 1818.

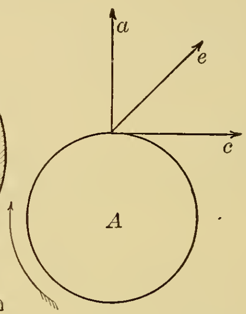


FIG. 2.
ASSUMED RESULTANT ANGLES.

I will add to these remarks on the centrifugal class of pumps by quoting from Prof. W. C. Unwin in the discussion of a paper I had the honor to present before the Association of Mechanical Engineers in London in 1888, on "Irrigating Machinery of the Pacific Coast":

What would most attract the notice of English engineers was the account given of centrifugal pumps, especially of compound centrifugal pumps. These had been proposed a very long time ago, having been described in Morin's book on pumps; but for some reason or other they had never found favor in this country, and comparatively few had been constructed in Europe. But obviously in California they had succeeded; and, looking at them from any theoretical point of view, they certainly ought to succeed. He could not conceive why, in many cases where centrifugal pumps were used in this country with moderately high lifts, the pumps had not been made compound. It appeared to him that the whole of the difficulty which arose in adapting the centrifugal pump to a moderately high lift was cleared when the pump was made compound. Perhaps some of the members might have seen in Manchester the triple

compound centrifugal pump designed by Prof. Osborne Reynolds, which was working with great success and, he believed, with considerable efficiency.

In page 39 of the paper it was stated that after the head reached 40 feet the efficiency of centrifugal pumps fell off rapidly, but he knew of some practical results which would contradict that, and especially from the theoretical point of view he could not conceive why at 40 feet head the efficiency should in any way diminish. The centrifugal pump was simply a reversed turbine, and turbines were being put up on falls not of 40 feet, but of 400 feet, and showed the same efficiency at the higher head as at the lower. He did not know of any instrument used by engineers in the design of which there was sometimes more recklessness of scientific considerations than was seen in the design of centrifugal pumps. Either a centrifugal pump was put up to work on lifts varying from 0 to 30 or 40 feet or, if the lift were constant, the pump was expected to pump sometimes 1000 gallons an hour and sometimes 10,000. No single machine like a centrifugal pump could possibly be adapted to such great variations of condition without working for a great part of the time at a low efficiency.

The low efficiency of the centrifugal pump had arisen chiefly from two causes. The first was that the pump was expected to adapt itself to the motor, instead of the motor being adapted to the pump. It was convenient to run an engine at a certain speed suited to the engine itself, and therefore the pump was wanted to run at the speed which suited the engine. The efficiency of the centrifugal pump, like that of the turbine, was very closely connected with the diameter of the pump, and, if good efficiency was wanted in centrifugal pumps, they must be made of a diameter which suited the lift. The friction of the pump increased something like as the fifth power of the diameter; whence it was to see that the waste of work, which was almost entirely friction in the pump, increased very fast if the pump was made of too large a diameter. The second cause of low efficiency in centrifugal pumps was the absence of proper arrangements for utilizing the kinetic energy of the water leaving the pump disc.

The first attempts at higher heads and pressures by cumulative action of centrifugal pumps in a commercial way was on this coast about 1885, and was reasonably successful; quite so in respect to endurance, as one machine, the second one made, remained in use for fourteen years, operating during the irrigating season. It is true that previous examples of multiple or cumulatively acting pumps had been made, notably those mentioned by Professor Unwin, in which a great number of stages were employed, but so far as known the system first assumed a practical importance on this coast at the time above named.

In England the cumulative system first took practical form in the pumps invented by Prof. Osborne Reynolds, patented there and in this country; but those acted by helical vanes combined with centrifugal ones, and as these two forces do not correlate or follow

the same law, except at certain specific relations, there was the impediment of adaptation to varying heads and speed of revolution that defeated commercially what was otherwise a very ingenious design and invention.

Following this came the Sulzer pumps that have achieved a wide celebrity and have obtained a very high efficiency, as noted on the table herewith made up from actual results.

Gallons raised per minute	285	444	634	870	1,400	2,060	3,170	4,120	5,706
Head in feet, one-stage	78	111	164	246	262	262	262	262	262
Head in feet, two-stage	157	223	328	492	524	524	524	524	524
Head in feet, four-stage	315	446	656	984	1,050	1,050	1,050	1,050	1,050
Efficiency, per cent.	67	70	72	74	75	76	76.5	77	77.6

Table shows results from four Sulzer pumps.

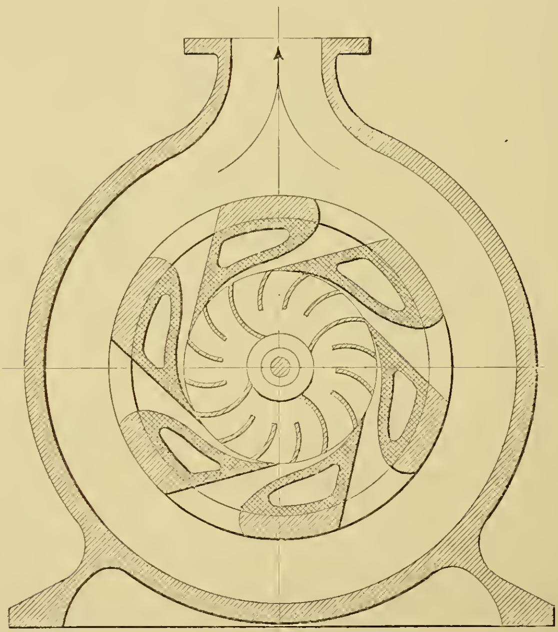


Fig. 3. Sulzer Pump, Cross Section.

Full publicity has been given to various instalments of these pumps, such as that at the Geneva Water Works and others in Europe, where the pressures were from 100 to 200 lbs. per inch and the efficiency attained as is noted in the table. In one case in Spain, at the Horcajo mines, a triple installation operates against a head

of 1550 feet with an efficiency of more than 70 per cent., and perhaps double what is usually attained with the ordinary displacement mine pumps connected in the usual manner. A full account of this plant is given in *Vereines Deutscher Ingenieure,* Vol. 45, of 1901, by Dr. F. Heerwagen.

Figs. 3 and 4 show sections of a four-stage Sulzer pump adapted to operate against a head of 800 feet, or a pressure of 387 pounds per inch. The drawings do not in several respects represent Messrs. Sulzer Bros.' present practice, but as no later plans have been published, I do not feel at liberty to disclose the con-

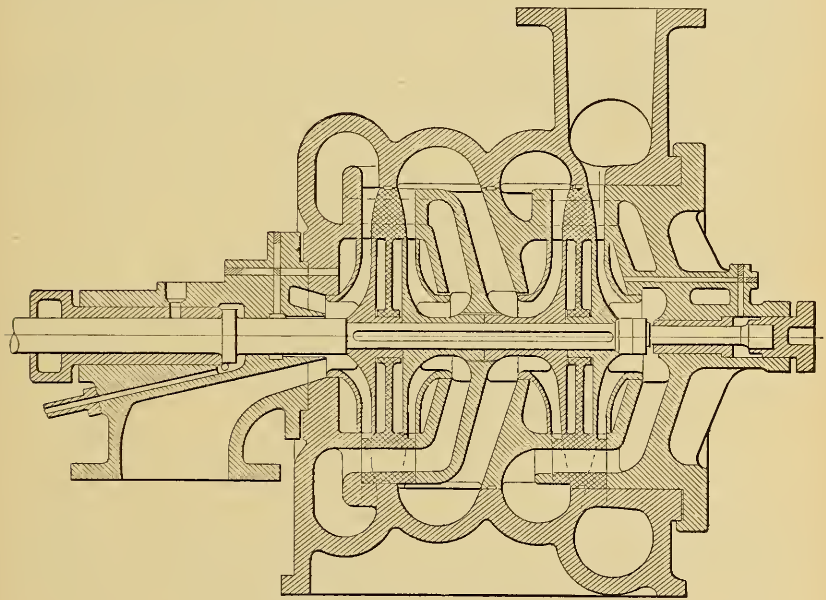


Fig. 4. Sulzer Pump, Longitudinal Section.

struction further than will be described in a future place and in another connection.

The extent and nature of the works at Winterthur I have described in a recent paper before this Society. They are well known all over the world and are again mentioned to say that the high-pressure pumps were more than five years in evolution and that the experiments made would have been impossible except by a firm with such extensive and suitable resources.

Coming now to the principle or manner of operating, which is no doubt the matter of most interest to the members, I have not provided the mathematical data that has entered into and greatly aided the construction of turbine pumps—to which class the Sulzer

type belongs. Computations, of which there is an abundant supply, belong in the drafting office and workshop. They are among the implements of construction, and a reference here to the work of Rankine, Bodmer, Reynolds, Unwin and others would not only be unintelligible without study, but would fail to illustrate so well as words do what it is intended to convey.

To intelligently describe the work of Messrs. Sulzer Bros. and that of the able engineer, whom they placed in charge of this work, I will have to introduce a digression which will serve two purposes—one, to explain the principles of the turbine type of pumps, and the other, failure of computation to define the curves and other operating features of turbine water wheels, to which, as before explained, the pumps are closely related.

It is well known that at the Centennial Exposition of 1876 there was conducted at Philadelphia an extensive and careful trial of turbine water wheels of the American centrifugal and Jonval types. Thirty-five wheels by different makers were entered and tested, giving efficiencies from 50 up to 87 per cent. These experiments were conducted by Mr. Samuel Weber and are embodied in a tabulated report now out of print, and, I may add, not very accessible at the time of publication, because made for the offices of the exposition only. I was present at some of these tests, secured a copy and have it at the office, 22 California Street, where it can be examined by anyone interested.

The tests were a surprise. The finely constructed Jonval wheels by Mr. Emile Guyelin and the best wheels of the Fourneyron type were all excelled by one made "out in Jersey," eighteen miles away, at Mount Holly, by Mr. Theodore H. Risdon. He was a maker comparatively unknown, with a small shop in a Jersey village, where he produced a plain-looking wheel that operated at 87 per cent. efficiency, the highest attained.

Other makers and even the Committee on Machinery were not satisfied, and Mr. Risdon sent his wheel to Mr. James Emerson, at Holyoke, Mass., for further and more complete trials, where the facilities were more extensive and reliable. This resulted in a surprise for the inventor and for the scientific world. The wheels gave out work up to more than 91 per cent. (91.3) of the theoretical or complete efficiency, the highest result ever obtained and not since equaled by any other turbine wheels of any type.

To explain this matter, turbine water wheels had previously been made with buckets or vanes with reversed curves, as shown in Fig. 5, taken from a Rodney Hunt wheel tested at the Centennial. In this wheel, which is of the centripetal or American inward

discharge type, the receiving or diffusing vanes, as will be seen, present a concave face to the impinging water, as indicated by arrows, this being a principle of construction well settled by complete mathematical data; but Mr. Risdon reversed all this, inverted the curves to present a convex face to the entering water, as shown in Fig. 6, which is taken from his wheels tested at Philadelphia and Holyoke in 1876. One of the complicated castings, which were absolutely true, uniform in thickness and smooth, is shown in Fig. 7.

I will mention, as a matter of interest to the members, that a similar casting was made here in 1888 for the Folsom Water Power Company under my supervision. Some of the wheels at Folsom failed and telegrams from the East assured the company that such a thing could not be done and it was perhaps the greatest "trick" in casting that could be proposed. The insertion of the cores

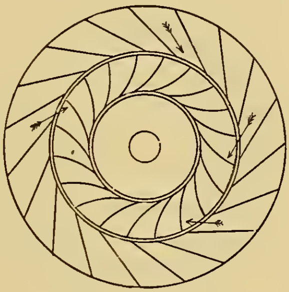


Fig. 5. Rodney Hunt Turbine.

seemed impossible. They had all to go in at once, less than half an inch at a time. The casting was made at the Occidental Foundry in this city, and the wheels, made of cold blast iron, are the best the company have in use at this time. It was only because the manager was ill and by knowing what Mr. Risdon had done that I had the temerity to enter upon this thing.

To show the connection between this matter and Messrs. Sulzer Bros.' work on turbine pumps, they began their high pressure pumps with the usual mathematical curves for turbine water wheels, and by a course of evolution, mainly experimental, have, without any knowledge of Risdon's work, changed the curves to his system, or approximately so. A compliment that, if Mr. Risdon were living, would have afforded him much pleasure.

I am not sure that other water wheel makers will confirm what has been said of the Risdon wheels. It is a matter of personal knowledge and acquaintance with the inventor, but an ex-

amination of modern practice will show that, upon the expiration of the patents on the Risdon wheel, his methods have been widely adopted. Those made here for the Folsom Water Power Company were essentially of the Risdon type.

In turbine pumps, as distinguished from the centrifugal class, the rotation of the water is avoided as much as possible, the object being, as in the case of water wheels, to have the water pass through the pumps with as little deviation from its course as possible. It is obvious that rotation of the water is not in the true course of its impulsion, but the resulting centrifugal force permits of a cheap and widely varied construction with adaptation to various uses where the narrow issues of a turbine would be objectionable. With proper conservation of the tangential energy attained by volute chambers and in other ways the efficiency rises to about 65 per cent. for large centrifugal pumps.

A good example is furnished by the large pumps at Codigoro, near Rome, in Italy, made by John and Henry Gwynne, of London, in 1874, that have been tested annually by the government and perform at about the efficiency named. There are in this plant eight pumps of 5 feet bore that raise over 656,000,000 gallons a day against a head of 12 feet, making a stream 103 feet wide and 4 feet deep flowing two miles an hour.

There are, of course, reports of much higher efficiency with small pumps, but my confidence in these trials was a little shaken some years ago when I sent the tabulated results of some centrifugal pumps made here, to Mr. Charles Brown, then Chief Engineer at the Sulzer Works, in Winterthur. He wrote a facetious reply, attributing the performance to the climate, as the quantities furnished would not work out the same way in the region of the Alps.

The final result to be attained by rotative pumps is now predictable, or, as the learned Mr. Gladstone would say, is "within measurable distance of reasonable conjecture." In a letter just received from Mr. William C. Brown, Chief Engineer of the Worthington Company, he concedes the possibility of attaining an efficiency of 80 per cent. with turbine pumps. He has himself done a good deal of experimental work, especially with induction pumps, in which the kinetic energy of the revolving water is applied inductively in the manner of an injector or ejector.

The attainment of high efficiency is not, however, the only problem. The cost of construction and the adaptation to use are equally to be considered. It is not to be a discovery, but an evolution. The experiments of Messrs. Sulzer Bros. and the recent ex-

periments in France by Rateau furnish a clue to what can be expected or is possible.

There is one feature in the evolution of all new machines not often considered; that is the time required to attain good workmanship. This seems to be as inevitable as problems of design and performance, and to require a like or longer period of years to work out. This is illustrated by the construction of tangential water wheels on this coast.

Twenty years ago these wheels had become a settled article of manufacture here, but were made in a crude, unsymmetrical form; not for want of skill, because fine, well-fitted machines were not an invention at that day any more than at this time. It is questionable, indeed, if manual skill was not better then, when fewer and less efficient machine tools were employed, but the fact remains of a gradual and slow progress in the quality of the manufacture.

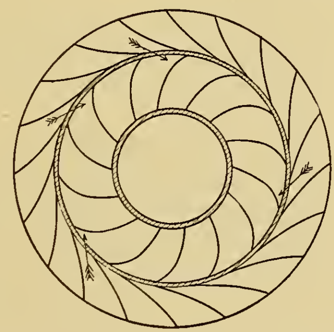


FIG. 6. THEODORE RISDON TURBINE.

It is only within two years past that I have seen well-made water wheels on this coast, well designed, well fitted and of good material, corresponding to many other kinds of machines that had been a constant example. This fault was, perhaps, not with the makers so much as with the purchasers of water wheels, but it amounts to the same thing in the end.

This impediment lies in the path of rotative pumps. For the higher pressures their cost or value permits a high grade of workmanship. The size and consequent cost of any fluid-impelling machine is, as a rule, inversely as the velocity at which the fluid passes through it, and the proportion between rotative and displacement pumps is about as five or six to one, the velocity of the water in the two cases having this relative flow through the impelling parts, the pistons and vanes; but it requires more than this fact to produce well-made rotative pumps.

There is also the impediment that the greater share of the pumps of the rotative type are, and will continue to be, for low pressures and of cheap construction, good enough for their purpose, and it will be difficult, not to say impossible, to set up and maintain in the same works two standards of workmanship so widely different. The interior surfaces, as Professor Sweet has recently remarked in a letter to the author, presents a problem as difficult as design.

It is not possible, in a common foundry producing general castings whose unfinished surfaces are a matter of little concern, to make complicated chambers that require true, smooth interior surfaces that should, if possible, be finished smooth. I am prepared to believe, after considerable observation, that much time, care and experience will be required to produce castings of the kind required for turbine pumps, and on which their performance must in some degree depend.

The great speed at which turbine pumps are driven, indicated in the table given, demands, also, very accurate turning, boring and balancing; but these are more easily attained than perfect and smooth castings.

Most people at this time look upon recent advances in rotative pumps as a discovery or distinct invention that will transform present practice in centrifugal pumps. This, I imagine, is not the case at all; centrifugal pumps will remain very much as now made and the high pressure or turbine that competes with displacement pumps will be a new class and a separate manufacture, although the same manner of operating may be adapted for all machines to pump reasonably clean fluids.

I feel warranted in saying this is the opinion of Messrs. Sulzer Bros., who also make centrifugal pumps of all kinds and have for many years past; but the two types—high and low pressure or turbine and centrifugal—are quite distinct, and are not even made in the same works. The centrifugal pumps are made at Mannheim, in Germany, and the turbines in Winterthur, in Switzerland.

In respect to pumping or compressing air or other elastic fluids with free-running rotative machines, there is hope and promise of considerable advance along the line indicated for liquids. Mr. Brown, as will be remembered, stated in his letter that Mr. Parsons was furnishing fans to deliver air at a pressure of 25 pounds per inch. This is done, I imagine, with one-stage machines, and is much more than is attained by centrifugal action in common fans, but is not a limit, certainly, because a second stage, beginning at 25 pounds pressure, could attain a second equal result.

These fans are driven by Parsons' steam turbine motors and the compression of air is the reverse operation. The analogy between turbine water wheels and pumps holds here the same, subject, of course, to the differences between an elastic and inelastic fluid, which, in so far as construction, is a very wide difference, because of the change of volume of the air as compression goes on.

Mr. George Manuel, C.E., of this city, has proposed the saturation of air with water so its gravity would be increased to a point when compression by centrifugal force would be possible at comparatively low velocities. This seems an ingenious expedient, but it is really a compromise with velocities, and, as the speed factor is fast being eliminated at this day, it is possible that the high velocities required for rotative air-compressing machines will become attainable. It is a problem of the strength of material, and

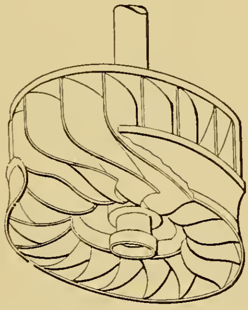


FIG. 7. RUNNING ELEMENT OF RISDON TURBINE.

this limit has been reached in steam and air-driven motors which move at only one-half the velocity of efflux, approximately 24,000 feet per minute for ordinary pressures. It must, however, be remembered that by operating cumulatively, by stages, these velocities can be reduced to a point where strong material can be relied upon. I mean for compressing machines, not for motors, because in these latter the initial velocity is fixed and corresponds to terminal or ultimate velocity in the compressing machines.

It will be reasonable to expect, in the next few years, conclusive experiments in rotative air-compressing machines, and, as the dimensions or areas of the ducts will diminish with pressure, it is possible that the economy of construction over positive or piston machines will be greater than in the case of liquids. It will call for a good deal of experiment as well as computation, but the result, if attainable, will repay the expense. Obviously, the makers

of such machinery in Europe have this matter in view. I mean such firms as the Parsons Company, in England; Rateau, also Farcot, of Paris, all of whom have this matter in hand. I mean higher pressures in free-running fans.

This paper had by circumstances to be prepared in two or three days, instead of as many weeks, and is no doubt incomplete in the same proportion. A portion of it has been done on a train after I left San Francisco, and I trust to your indulgence and that of the Secretary, who will have to digest and present a rough lot of notes.

NOTE BY THE AUTHOR.—In reading the proofs of the present paper and the discussion that followed I can see some omissions that can be added with advantage.

The curve or shape of the vanes of a purely centrifugal pump is a matter of no consequence, except as affecting the speed of revolution or of volume which is, within certain limits, the same thing. Their function is to set the water in revolution in the pump, and this they will do with like effect whatever their number or shape; but in the turbine type of rotative pumps the form of the vanes becomes very important, as in the case of water wheels. Their angle to the radius is a measure of their proper velocity, and the component of the angular or vane velocity and that of flow is reduced to a computable problem.

The resistance caused by rough surfaces is the same as in the case of conduits and pipes in which velocity is the controlling factor. The same rule applies to bends and reversals, of course; but the interior of impellers being subject to slow flow, generally less than that in the induction passages, does not offer much resistance in centrifugal pumps.

One point of considerable importance I omitted from the paper because of a want of information on my own part. I allude to what our old friend Mr. Stevenson calls "kinetic stability." It is an obscure matter. A mass of water in rapid revolution in one plane as in the case of the disc in a gyroscope, can be moved laterally or discharged tangentially without opposing its tendency to remain in one plane, or its kinetic stability. The measure of this force and its laws I am not able to refer to; but in my own practice I avoid the diversion of the water from its plane of rotation, as in the case of series pumps where the losses are cumulative.

It will be a matter of surprise, no doubt, to know that the losses due to action by stages have been nearly eliminated. This has been recently shown here by our able member, Prof. F. G. Hesse, of the University of California, and the problem has engaged my own attention in a practical way for two years past. Engineer Stevenson's propositions relating to the relations between kinetic stability of bodies and the laws of gravity may have seemed to us chimerical; but in rotative pumps its place and functions are more apparent.

NEW YORK, June 28, 1902.

DISCUSSION.

Mr. Grunsky.—In ordinary California practice what is the efficiency of low-lift and high-lift centrifugal pumps, and what lift has become customarily adopted here for compound pumps?

Mr. Jackson.—In ordinary practice we expect from 60 to 70 per cent. efficiency in standard centrifugal pumps. The highest efficiency, however, is obtained in special pumps under favorable conditions. It is necessary that the pump shall work at its full capacity in order to get the best results. These conditions being satisfactory, we have records, from careful tests by experts, of 70 per cent. and over—even as high as 83 per cent. In my own practice and standard work we have installed single pumps for heads from 100 to 150 feet, but we have also made series 2 and 3-step pumps for 100 feet head, because we are called on to make direct-connected plants to electric motors and steam engines, and it is easier to adapt the pump to the speeds of the motor and engine than to make special motors to suit the speeds of the pumps; and we are able to make this change of speed either by changing the pump or runner or by adding more steps.

We have recently made a test with a 2-step series pump furnished the Bay Counties Power Company. The plant was originally made for a 400 feet lift in 4 steps; but, after making the order, the company changed their plans and installed only two pumps in series working against a head of 200 to 240 feet lift. One of my engineers, with the company's engineer, made the test. Both were skilled men, and their record for the tests show a combined efficiency of 73 per cent. and the pump 83 per cent. efficiency at a head varying from 211 feet to 240 feet. The pumps were driven by belt from a countershaft connected to the motor.

I have the records of another test, made by the Spreckels Sugar Refinery Company, Mr. Waters, Superintendent, who made the test for his own information before placing an order for another pump like it. The record shows 68½ per cent. combined efficiency and 76 per cent. for the pump only. The head was 68 feet. The pump was a special 18-inch pump, direct-connected to electric motor, having capacity of 10,000 G. P. M., dirty water from the sugar refinery.

Mr. Dickie.—For high heads, do you think it is advisable to use the type of pumps we have shown here in the Sulzer pumps?

Mr. Jackson.—Your question embarrasses me, because I do not feel like criticising others. I will make this broad statement, however, that in the construction of pumps it is not advisable, in view of the item of cost, to try to make use of the kinetic energy

by introducing the diffusing veins or guides, as it appears to me that they would be more of an obstruction to the water than otherwise. Besides, I do not find it necessary to take the suction in on opposite sides of the runner in order to balance it, but I confess I have not made any experiments in this line. I prefer the shortest road possible, as I am a manufacturer of pumps for the sake of making money, and at the same time have doubts as to the utility of these diffusing veins.

Mr. Dickie.—Don't you find that the character of the castings, the surface of metal, have a great deal to do with the efficiency of pumps? I refer to the necessity of smooth surfaces. They must have a very important bearing on the efficiency of the pump.

Mr. Jackson.—Yes, I agree with you. We have made a great many pumps with split runners for the purpose of polishing the inside waterways, also making them of brass so that they would not rust; but this is done only in city water works, where the efficiency is very important. For average use, I do not believe it justifies the expense. In many cases the water carries so much sand as to wear out the runners in a short time. I depend much on the skillfully and carefully made core work. We frequently take a great deal of pains in washing and smoothing them so there will be no unevenness.

Mr. Dickie.—I think that, in pumps like these, this feature is of great importance, the direction changing so often as the water passes through the pump.

Mr. Jackson.—I fully agree with you on that point.

Professor Wing.—Mr. Jackson, how many different forms of curves for different or various vanes of pumps have you adopted?

Mr. Jackson.—Only one form of curve. Always back, never forward. To meet different conditions we turn the curve back more or less. In that sense we make many different curves; but I should like to hear what results have been obtained from veins turned forward, as I cannot see any good results for turning them forward and do not know of any builders adopting it. When I first commenced the pump business, some twenty years ago, I made tests with medium-sized pumps with seven different curve veins from a straight to a very sloping curve. The curve affected the efficiency but little, but affected the capacity materially. I have never seen a formula in any work on centrifugal pumps that included any other force than the centrifugal. Now, I think the force of impact on the curved vein is more important than the centrifugal force, because the discharge velocity of water at the

periphery is never that of the runner, but in some cases is little more than the average velocity of the discharge in the pump's scroll or pipes. This paper suggests many subjects that it would be very difficult to talk about on the spur of the moment, especially in the matter of compressing air by centrifugal runners. I think a machine of that character would tend more to work for evolution in mechanics than either the compound or centrifugal pumps.

Mr. Grunsky.—I would suggest, Mr. President, that there might be some written discussions on this paper, and the Society would certainly welcome a discussion in correspondence that could be published in connection with this paper. It is certain that the possibilities indicated by Mr. Richards mark this subject out as a field of great promise. The coast here has certainly done its share in overcoming the difficulties in connection with the construction of this type of pumps, and it would be well to ascertain definitely what the coast has done in this line. Mr. Jackson's utterances are an indication of what we might hear from others.

Mr. Luther Wagoner.—The principles of compounding centrifugal pumps and fans are well illustrated in the abstract of Professor Rateau's experiments, made last year (*Engineer,* March 7, 14, 1902). Single, 5-wheel and 7-wheel pumps were tested, and the results are given in numbers and also by diagrams. The notation employed is simple and independent of dimensions, and the resulting diagrams are characteristic curves which co-relate the mechanical, volumetric and manometric efficiencies. They will repay careful study by those engaged in designs for improving such pumps. The data mentioned above are sufficient to test the theory of Professor Hesse, as expounded in a paper read before this society last year;* and a careful mathematical discussion of it would doubtless throw much light upon the principles of rational design.

The experiments upon fans driven by steam-pelton wheels show that it is possible to produce a compression of 1.5 atmospheres by a single fan. Hence, if four or five wheels were compounded, it is possible that a light and cheap form of air compressor could be made. Such a machine, directly driven by an electric motor, would make the use of compressed air easy of application in many places where it is now excluded by reason, either of the size of the ordinary type or the length of pipe required. Cheapness and portability would offset a considerably reduced efficiency.

*"The Efficiency of Compound Centrifugal Pumps," by Prof. F. G. Hesse, Journal of the Association of Engineering Societies, Vol. XXVII, No. 6, December, 1901.

Mr. L. J. Le Conte.—One of the many anomalies in applied mechanics is the comparative lack of development in the theory of the ordinary centrifugal pump as compared with the well-developed theory of the turbine water wheels, which has been brought to great perfection.

Broad general theory would lead one to suppose that the centrifugal pump was simply a turbine wheel with reverse action; but this view, when applied to the ordinary centrifugal pump, leaves imperfectly explained many well-known facts, and consequently the apparent parallelism is not altogether clear.

For example, the turbine wheels have a high and practically constant efficiency, whether the working head be 50 feet or 500 feet; whereas, with the ordinary centrifugal pump, for lifts over 75 feet the efficiency decreases much faster than the head, and the height is soon reached where the pump has an efficiency so low as to destroy its usefulness.

This fact must be due to some natural resistance in the centrifugal, which does not exist in the turbine water wheel; and the question rises, what is the true cause of this abnormal prejudicial friction, which develops as soon as the ordinary centrifugal pump begins to run at higher speeds?

The writer is led to think that Professor Hesse, of the University of California, has settled many doubtful points by experiment. He seems to show conclusively that the runner disc friction is a powerful element in the problem, and one which has not been properly considered by writers heretofore. He finds that the loss of energy, per second, varies directly as the square of the diameter and as the cube of the velocity of the periphery.

It is, therefore, clear that the ordinary centrifugal pump, as now constructed, is poorly adapted to high lifts, because of the high runner speed necessary to perform the work required. This important fact has led to the rational conclusion that for high lifts, a proper system of compounding would reduce the speed of runner for a given delivery, and, by this means, greatly improve the general efficiency. Experience has proved this conclusion to be sound and very important.

Other able writers maintain with much force that this loss in efficiency at high speed is chiefly due to lack of complete arrangements for utilizing the kinetic energy of the water as it leaves the periphery of the runner. This view seems to be well substantiated by experiments given in the table showing the results attained by the Sulzer compound turbine pumps, which is certainly very remarkable and worthy of the highest praise.

Experiments have shown the great value of *guide-vanes* in turbine pumps and their effect upon the efficiency. Mr. Parsons found that a given pump, *without guides,* delivered 1500 gallons per minute; while the same pump, *with guide-vanes,* delivered 5000 gallons per minute, the same steam pressure being maintained. Hence many engineers insist that the ordinary volute or centrifugal pump, at high speed, does very ineffective work in converting into pressure the kinetic energy of the water leaving the runner. There seems to be much force in this contention, and this at once suggests the propriety of introducing *guide-vanes,* similar to those of the turbine pump.

It is more than likely, however, that both these views are correct—within their own limits—and that the best results may yet be obtained by giving proper weight to both in each particular case. The whole past history of advancement in mechanical knowledge is full of such examples.

Taking a broad view of the author's valuable paper, which is pregnant with valuable suggestions, the most interesting feature is the remarkable results obtained by compounding. These important results open up a wide field of usefulness for centrifugal pumps, which their most ardent advocates do not yet fully realize.

Mr. A. E. Chodzko.—The copy of Mr. John Richards's paper on "Rotative Pumping" was duly received and read with great and much-deserved interest. Mr. Richards's remarks about the steady inroads made by direct impulse or so-called rotative upon reciprocating machinery, only confirm what he said and wrote on this subject at a time when high-pressure machines of that type, either motors or driven, were in their infancy, and attracted no attention on this side of the Atlantic, except from a purely scientific standpoint. I believe that Mr. Richards may rightly be considered the pioneer of this class of machinery on the Pacific Coast.

But while a decided trend toward continuous action clearly appears in the motors, whether steam, hydraulic or electric, the progress has been less general with driving or operative machines; I mean, with those designed to generate pressure, and whose action is, in principle, the reverse of that applied to the corresponding motors. This statement does not include the electric motor, which has made parallel strides with the dynamo. Hydraulic machinery, which furnished the subject of the present paper, has of late years made some most remarkable progress. Regarding what is said of Mr. Theo. Risdon's innovation, in using convex instead of concave diffusing vanes in his turbines, with such satisfactory results, reference may be made to the form of the so-called Berry buckets,

described by Mr. Richards some years ago in a pamphlet on "Tangential water-wheels," which at that time elicited very bitter criticism from some makers of tangential water-wheels of the concave bucket type. The continuous compression of gases is apparently the least advanced chapter of the series. It was after reading a passage of a letter written by Mr. Chas. Brown, of Winterthur, Switzerland, and communicated to me by Mr. Richards several years ago, that I began to investigate the subject, first, analytically, and, later on, in an experimental way. I have recently built and operated some machinery designed for this purpose, and I firmly believe in the possibility of raising gases to high pressures by the direct-acting rotary process.

The practical requirements are many and peculiar, and the problem is by no means easy to solve; but, as one acquainted with the operation of reciprocating compressors, I concur with the paper under discussion, that the result will repay the labor.

PAVEMENTS IN GENERAL.

By Charles E. P. Babcock, Member Engineers' Society of Western New York.

[Read before the Society, February 4, 1902.*]

In the fall of 1896 Mr. March read before this Society a paper on "Paving Brick and Brick Pavements," and his paper was published in the transactions of the Engineers' Society. So completely did Mr. March go into the subject that but little can be added.

Still later, Mr. Bardol, at that time Chief Engineer for the Bureau of Engineering, in his report for 1898 brought together much material on the subject of paving in general.

Many others have written on pavements and paving material, and it seems as though but little is left of the subject but personal experiences.

The following notes are gathered from observation and are in no wise intended to commit the profession:

ASPHALT.

When a pavement fails, the most frequent explanation is that the foundation is poor; but this is not always the correct reason. Nearly all of our asphalt is laid on a concrete base, a few streets have a bituminous base, and in several the old paving stone was used for a base and covered with the asphalt binder and surface. The concrete is of natural cement, mixed 1, 2 and 5, laid 6 inches thick. At Niagara Falls a 4-inch base of Portland cement concrete is laid 1, 3 and 10. The objection to the natural cement concrete is that it is apt to be porous, and, if water does reach it and remains upon it, the concrete becomes soft. In streets where new surfaces were laid, this softening was sometimes very marked, but in every instance after we laid drain tile and left the concrete exposed to the air and sun for a few days it hardened satisfactorily.

In Linwood Avenue, resurfaced in 1901 from Balcom to Delavan, in the first 200 feet north of Balcom a gravel was found in the curb trenches. This was immediately under the concrete, which was hard and dry; but further on we found clay, and the concrete was soft and damp. Drain tile had not been used, but was provided at the time of resurfacing. On Main Street near Ferry, resurfaced in the same year, the concrete was very hard and smooth and looked as though a glacier had worked over it. This part of Main Street

*Manuscript received August 8, 1902.—Secretary, Ass'n of Eng. Socs.

had, under the concrete, a sand bed, which had been used when the street was paved with stone. These two streets had asphalt pavements of about the same age. Linwood Avenue was laid in 1885, and Main Street in 1886. Both required a new surface at about the same time. In Linwood Avenue the concrete was generally soft and damp, in Main Street it was hard and dry. These are cited as instances where the failure of the pavement may not be due to poor foundation. When the life of the asphalt is gone, the pavement follows very closely. The life of the asphalt pavement is the asphalt or bitumen which binds the small particles of sand and stone dust. Without the asphalt we would have nothing but the concrete base, with about 2 inches of sand and smaller material on top. In the Macadam road the sand is the binder, but it has a depth which the asphalt surface has not.

About 11 per cent. bitumen is expected in our pavements, and there is no disposition to furnish less, as we require from the contractor a guarantee for maintenance for ten years. This has been the case since 1898.

But the streets that have disintegrated are those laid prior to 1898 and guaranteed for only five years. In some instances, early disintegration was due to insufficient asphalt or inferior quality. The streets were relaid at the expense of the contractor in most cases—all but one. There were not many of this character; they made the guarantee expensive.

Rolling in the surface is another phase which generally leads to breaking up, and it seems impossible to prevent such roll or waves as are due to travel. It may be noticed that these occur on each side of the street, but not in the middle third. Probably, if the course of travel could be changed so that part of the time the line of travel would be on the left of its direction and then back on the right, changing about at intervals, there would be no waves in the surface, or, at least, they would be at a minimum.

Prospect Avenue south of Porter, and Delaware Avenue south of Virginia Street are good illustrations. Both streets were formerly paved with stone on a sand bed; the grade is steep enough, and both were laid under favorable conditions and in a locality where they would stand as witnesses to the skill of the contractor.

They were laid by the Barber Asphalt Company and were smooth and really beautiful streets for a few years. Then the waves appeared. A general disintegration has not yet begun, though considerable repairs have been made.

The bicycle has done its share in making the waves. There is a difference in traction between the rapidly-moving bicycle with

rubber tires and an ordinary load on four steel tires. The automobile and its kind will probably demonstrate in a more marked degree the action of the bicycle, both being propelled vehicles as distinguished from the wagon which is drawn. It seems certain that this rapid propulsion, always on the right side of the street, must, on hot days, push the softened pavement out of position, but it is noticed only when the travel is very great. Other pavements might show in a different way the action of these propelled vehicles, but perhaps not so early as they would the wear and grind of the horses' shoes and the steel tires. But the very nature of our asphalt pavements make them susceptible to this action, which may not be so apparent in the rock asphalt. In any event, the comfort of the modern vehicle should reconcile the user to the cost of maintaining the smoother pavements. While easy to clean, they also make the presence of dirt more noticeable and its removal more of a necessity. In their own sphere they have done more missionary work for cleanliness than the fiercest crusade of the Health Officer.

The action of frost does not seem to have heaved our pavements to any serious degree, because so little moisture accumulates under them. Some exceptions may be found on streets where asphalt is laid flush with rails of street car tracks and where the rails are not on a permanent base.

Expansion should not hurt the asphalt in this climate, but hot weather renders the surface susceptible to the action of travel; and, where petroleum residuum is used as a flux, the hot weather cannot improve the surface.

Severe cold has caused cracks, but it is not certain that these do much harm in a comparatively new pavement, so long as water does not work in. The cracks seem to close up and adhere in warm weather. Steam rollers are used in making the surface, the idea being that immediate and great compression is required. Much experience would tend to show that a less initial compression would give a smoother surface. It can not be said that the steam rollers are entirely unsatisfactory, for some very fine surfaces have been obtained with them and for finishing they are indispensable; but it often happens that the finished surface is not even. This is due to either a movement in the foundation, a heavy, working engine, a careless steam engineer or the condition of the asphalt at the time of rolling and sometimes the weather. Different kinds of asphalt require different treatment in rolling as in other handling. It has been the experience in Buffalo that when the pavement is rough at time of completion; that is, when it shows small waves, subsequent travel does not eliminate them, though statements to the con-

trary are made. But cuts in the new pavement from horse shoes and wagon wheels generally disappear under travel in warm weather. It is not possible to say that the asphalt surface is invariably 2 inches thick, as required by the Buffalo specifications, but we have found from experiment that a square yard of newly-laid pavement 2 inches thick should weigh from 180 to 195 or 200 pounds, according to the mixture; and we know the weight of a load of the surface and can spread this load to cover the area it should.

Asphalt from the Island of Trinidad, when refined, analyses for about 56 per cent. of bitumen, Bermudez for about 97 per cent., Alcatraz for about 98 per cent., Obispo for 99 per cent. and Cuban asphalt 70 per cent.

Reports of investigations sometimes tend to show that one asphalt is superior to another because of its higher percentage of bitumen after refining, but this has not been borne out by facts. From a commercial point of view, one may be more profitable to handle than another. The quality of the bitumen must be considered, and not merely quantity derived after refining. Its natural limpidity is of high value, but if this is obtained by artificial means the result is not always the best. Trinidad Lake and the so-called Trinidad Land asphalt analyze for about the same amount of bitumen. We have the report of a chemist on some of the land asphalt in which he expressed the opinion that it was suitable for paving. Streets laid with it were soon in bad condition and were resurfaced with lake asphalt at the expense of the contractor.

In treating some of the asphalts for a paving matrix, petroleum residuum is used as a flux. Trinidad and Bermudez are prepared in this way. The use of this mixture affords a subject for considerable thought. To the student of mechanical or physical forces it would seem that the introduction of anything of an oily nature would not give the best results. We use the asphalt solely in order to bind together the small particles of sand and stone dust; but, to obtain a certain and uniform softness, we use oil as a flux. The percentage of oil is, of course, very small, but its presence at all is undesirable. The petroleum residuum probably contains some petrolene. At any rate, its addition to the refined Trinidad asphalt increases the percentage of bitumen from 56 to about 62, and there seems to be no chemical reason why it should not be used as a flux; but, from a mechanical standpoint, the introduction of anything that may act as a lubricant is ill advised.

When the first asphalt was laid here by Abbott, he used a built-up base of broken stone—not cement concrete—and in the surface

he used Trinidad asphalt, with wax tailings for a flux. The surface also contained a small gravel and broken stone, mixed in with the sand. One of his pavements failed after about 14 years use and a new surface was laid; but the other pavements laid by him have proved excellent. His explanation of the failure was that the pavement was deficient in quantity of asphalt. His use of small stone or gravel and sand is interesting when compared with the practice under our ten-year guaranty, in which sand is the component of largest dimension and a very fine stone dust the smallest, except possibly the carbonate of lime.

A California maltha is used as a flux for the Alcatraz asphalt. It contains a larger percentage of bitumen than the petroleum residuum and seems better suited for a flux; but our experience with the Alcatraz has not been of sufficient duration to fix its value as a pavement. The Alcatraz and other California asphalts are refined by cutting with a light hydro-carbon, such as naphtha. They are then carried over evaporators and different grades obtained. Whether this is preferable to the heating or distilling process of separation I cannot say, but I prefer the latter.

Much expensive chemical analysis has given knowledge as to the components of the asphalt and has recorded their names and percentages. A similar professional consideration of the mechanical combination of the components would have given us as good an asphalt as it is possible to mix, but this consideration is not always given. The mass should be one with minimum voids, one which will lay smoothly and retain its surface, whose particles will not roll on each other and which will resist the decomposing action of refuse and water and wear well.

The imported limestone or rock asphalt makes a very serviceable pavement; yet a short time ago an argument made in court was to the effect that the action of water on limestone was erosive and that, therefore, an asphalt with limestone in it was not so suitable as a mixture of refined asphalt and selected sand. This argument was not made against the imported rock asphalt. The pavements as now laid here; that is, the refined asphalts, contain more or less pulverized limestone, because that is the stone we have in our quarries. The advantage the natural rock pavement has over the made-up asphalt seems to be that nature has thoroughly filled (or, we might say, saturated) the rock with the bitumen in the natural rock, and there must be an absorption of bitumen and an adhesion that is difficult to obtain by mechanical process. The advantage of the latter is a commercial one. It enables us to use a material which, by proper handling, may be well enough suited for its purpose.

Criticism of our pavements should be tempered by a thoughtful consideration of the circumstances under which they were laid. The cost of paving is borne by abutting property. When asphalt was first laid here it was so much better than the common stone or wooden blocks that there was a demand for it at a greater cost. The asphalt company, having its patents, furnished its specifications for mixing and laying, with a maintenance guarantee for five years. These specifications have not been materially changed, except as to amount of bitumen used and period of guaranty. Contracts were awarded on representations of a majority of persons liable to pay for the improvement. In many instances the pavement was laid in front of vacant property, which it improved and made marketable, so that often the owner could more than afford to pay for the pavement. This was done without the special advice of the engineer, whose office seemed to be to superintend the work which someone had asked for under certain specifications. Most of this pavement lasted five years,—the period of guarantee. If not, it was replaced by the contractor. But, after ten or twelve years, when it began to wear out and the repairs paid for by the city amounted to several thousand dollars a year, came criticism and some denunciation. How far the engineer could have shaped things, it is not easy to say. Without facilities for laboratory experiment, and restricted in handling patented pavement, there was not much for him to do in the way of initiation. If decision as to kind of pavement to be laid were left to the engineer or to someone else competent to recommend, there would be an occasional opportunity for improvement without waiting for the willingness or profit of the contractor. Under the conditions as they exist in Buffalo, the best safeguard against a poor pavement is the ten-year maintenance guarantee. Mr March, in his paper, quotes Mr. Male, a French authority in asphalt pavement, as saying that the cracks in the pavement are largely due to the use of oils for fluxing, and he deprecates the use of petroleum residuum.

Little, if any, of the kinds of asphalt used in this country is used abroad. Most of the foreign asphalt pavements are laid with the natural rock asphalt.

STONE.

The wear on our better class or block stone pavement has been comparatively light. It has been in use since 1887. Most of it was laid on a well-settled bottom, with concrete base, replacing old stone pavement laid in sand. The Medina sand stone, which we use, has a tendency to wear off smooth, not slippery, as granite does, nor is it so durable as the granite. The cost of the latter in Buffalo would be prohibitive. The Engineer's office has attempted to obtain

a better grading of size than is furnished; that is, to have blocks nearer the same area on top; but we are more or less guided by the quarrying interests. Of course, the quarry will furnish any sizes called for, but the cost must be considered. Just at present the blocks run a little too large. For a while they came very close to our specifications. In fact, the specifications were the result of investigation from our own and the quarrymen's standpoints.

In some of the stone-paved streets the joints were poured with either asphalt or paving pitch, hot gravel having been swept into the joints. This is satisfactory. The joints must be sufficiently wide; and gravel, not sand, must be used. Asphalt, heated to its extreme, will not run into a sand joint. The largest gravel the space will contain should be used. Of late, we have laid the stone blocks as close together as possible and used a good Portland cement grout for filling the joints.

BRICK.

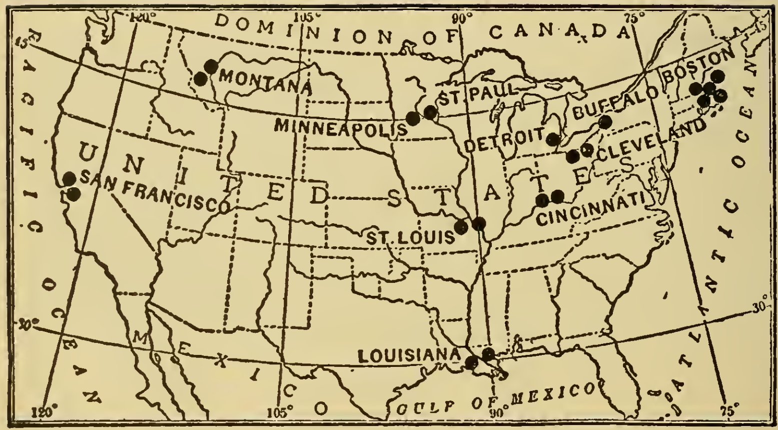
New kinds of brick are coming into the market. In fact, the kinds are so numerous that we now specify the round or square-edged, fire-clay or shale, meeting certain requirements as to absorption, abrasion, etc. We now pour all the joints with cement grout, leaving an occasional expansion joint of sand. Tar is not satisfactory. We have never used asphalt for this purpose. Brick is the most difficult pavement to repair neatly. It seems impossible to relay brick to the same surface as the undisturbed contiguous brick. To date, our brick pavements have required but slight repair. The first laid under contract was in 1891.

CONCRETE.

In mixing concrete, the proportions of the components should always be worked out according to their sizes or voids. In experimenting on our street work, we have found that the bag of cement such as we use, about 2.25 cubic feet, with sand and gravel and broken stone, laid about 3.12 square yards of concrete 6 inches thick, whereas the use of sand in place of the gravel made about 2.73 square yards, or about 90 per cent. of what was obtained in the first mixture. Concrete, as laid in our paving work, with good organization and with the materials on the street, can be mixed and deposited at the rate of about one-half cubic yard per hour per man.

As to the value of the concrete base for pavement, nothing need be said to the engineer. But, if in our new streets we were content to lay a stone base, in fact, a good macadam, wait until it has worn down to its bearings and then lay on this base a suitable surface, there would be little complaint as to durability.

We have, now, over 337 miles of paved streets, or 6,384,000 square yards, the cost of which has been about $20,000,000, or over $50 per capita.


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BOSTON
BUFFALO
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
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ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°

ASSOCIATION
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THE HENNEBIQUE SYSTEM OF ARMORED CONCRETE CONSTRUCTION.

BY LEOPOLD MENSCH, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, June 10, 1902.*]

IRON and steel have been used in the construction of railroads, steamships, bridges, office buildings of stupendous heights, factories, exhibition palaces, markets, theaters, apartment houses, grain elevators, water towers, stand pipes, smoke stacks, and water mains of hundreds of miles in length. Even churches have been built entirely of iron. It is due to the triumph of iron and steel engineering in the latter half of the past century that our profession is recognized to-day as one of the most honored of human vocations.

I ask, is steel really the most suitable material for all these purposes? Is the engineer (who is defined as a person employing the resources of nature with the least amount of human labor to the benefit of mankind) right in using steel only as the skeleton of his constructions? The universal reign of steel is irrevocably past, and we are returning with rapid strides to the old, time-honored masonry construction.

Not to brick or stone work, but to an artificial stone, *i. e.*,—concrete, strengthened by steel. This composite material is variously called concrete-steel, ferro-concrete, or armored concrete. Concrete itself is not a new building material. Vitruvius Pollo, the famous writer on architecture and engineering, who lived in the beginning of our era, describes it as one of the most valuable building materials, and as one which, centuries before his time, had been used for foundations, for walls and in all structures where great strength was required. The great dome of the Pantheon, in Rome.

*Manuscript received July 1, 1902.—Secretary, Ass'n of Eng. Socs.

142 feet in diameter was built entirely of concrete, and it stands to-day, having braved the destructive influences of nature for nearly 2000 years. In the House of the Vestals, an upper floor of 20 feet span was a simple slab of concrete 14 inches thick. Even in Mexico there are buildings, the remains of an unknown civilization, which have concrete foundations, and in the Italian colonies of Magna Græcia, there is evidence that the ancient Greeks knew what concrete was and how to apply it. The walls of Reading Abbey, in England, were apparently faced with square blocks of stone on both sides, and the core and backing were made of concrete, with the result that, although the stone appears to have perished, the concrete, which was intended to play a secondary part, still remains.

At Badajos, in Spain, the walls of the castle and fortifications still show the marks of the boards used for the molds. In all parts of the world there is evidence that concrete, as a building material, was well known and largely used many hundred years since, long

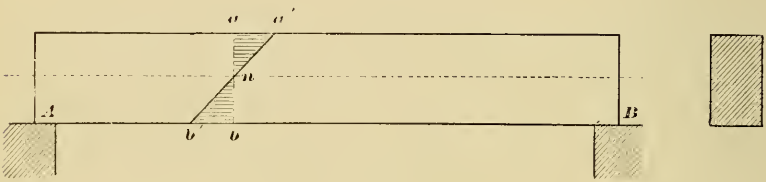


FIG. 1.

before the general introduction of steel and other artificial substances, now recognized as legitimate materials of construction. As Portland cement was unknown eighty years ago, all the concretes named had lime for their cementitious constituent; but the excellent quality of the lime, and the apparent care and knowledge applied in the selection of the component parts, resulted in the construction of buildings superior in strength and durability to any of modern erection, skyscrapers not excepted.

The use of concrete alone, however, is confined to that limited number of cases where economy in time and labor does not enter into consideration. This is because concrete has a comparatively high compressive strength, but a very low tenacity, thus forming, like cast iron, a very uneconomical material of construction. To illustrate this point further, let us consider a concrete beam, AB (Fig. 1), of rectangular section, supported at the ends and loaded. The beam will deflect, the upper fibers will be in compression, the lower fibers in tension. The greatest stresses occur in the extreme fibers at top and bottom and are of the same magnitude. The nearer we come to the center of the beam, called the neutral axis,

the less will be the stresses. Their distribution in any section of the beam is graphically represented by the diagram a a′ n b b′. The greater the load the greater will be the extreme fiber stresses, and, in increasing the load, we reach a point where the ultimate tensile strength is reached and the beam fails. It fails because the lower part of it, which is in tension, is destroyed, while the upper part is strained to only from one-tenth to one-twentieth of its ultimate strength, concrete having a tenacity of about 200 to 250 pounds per square inch and a compressive strength of 2000 to 3000 pounds per square inch after two months, which might increase to 5000 pounds after two years. This unfortunate property of concrete can easily be remedied by embedding steel rods where tensile stresses might occur. This expedient, however, is not new. Monier, a Frenchman, as early as 1876, took out his first patent on concrete-steel construction, and thousands of water tanks, sewers and water mains were built of concrete armored by wire nets, and a new field and new

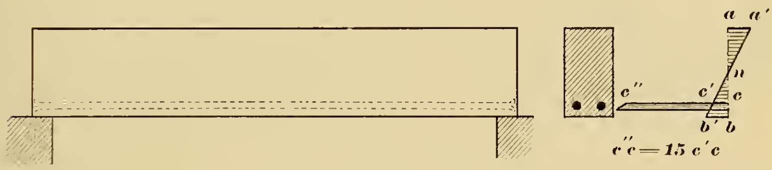


FIG. 2.

possibilities were opened, which will soon revolutionize our building practice.

All rational combinations of concrete and steel are based on the following facts:

First. The coefficients of expansion of concrete and of steel are practically equal, as many scientists of Europe and America have demonstrated.

Second. A perfect bond exists between concrete and steel. Their adherence has been determined by different authorities, and found to be 570 to 650 pounds per square inch.*

*It may be interesting to know what the length of an iron rod, embedded in concrete, must be in order that it may fail by tension before rupturing the bond. If we assume the ultimate tensile strength of iron to be 57,000 pounds per square inch, we have the force required for breaking the rod bodily = $57{,}000 \frac{\pi d^2}{4}$; for breaking the bond the force required = $l\, d\, \pi \times 570$; $l\, d\, \pi$ being = area of surface in contact. Equating these two expressions, we get, as minimum length, $l = 25$ d. Thus, if a bar of round iron has a length of more than twenty-five times its diameter, it will break before it can separate from the concrete.

Third. The concrete fully protects the iron against corrosion.*

We know, besides, that iron nails were preserved by the mortar of Roman walls for 2000 years, and in view of this fact can we doubt the preservative efficiency of our first-class Portland cements?

Fourth. The ratio of the Moduli of Elasticity of concrete and steel is as 1:15. In other words, if two fibers of concrete and of steel, respectively, of the same length, be subjected to equal elongations, their stresses will be in the ratio of 1:15.

Let us now revert to our concrete beam, imbed steel rods in the lower part and apply our loads. The beam will again deflect, the upper fibers will be in compression and the lower fibers in tension; but the diagram of stresses, which in Fig. 1 was represented by a a′ n b b′ is now distorted by the new stresses which are produced in the steel rods, forming the diagram a a′ n b b′ c′ c″ (Fig. 2). We have learned that a perfect bond exists between the steel and con-

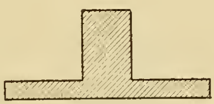


Fig. 3.

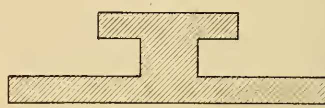


Fig. 4.

crete, therefore it is evident that the extension of each steel fiber is the same as that of the adjacent concrete fiber. But, by the fact stated above, this involves stresses in the steel fibers fifteen times as great as in the adjacent concrete fibers, since these are necessarily

*An experience of 2500 years has proved that concrete is absolutely indestructible, that it resists the disintegrating effects of air, moisture, water and steam, even of sea water and of sulphuric and chlorine gases; and that, if the metal embedded in concrete were not thus protected by the latter, concrete-steel structures would be impracticable. Happily, however, wherever such work has been taken up after years of exposure, the steel has been found free from any trace of oxidation. To remove any possible doubt, Mr. Hennebique resolved to urge upon the city authorities of Grenoble, France, an official investigation into the preservation of steel in concrete. In that city a water main, constructed on the Monier system, of 12 inches internal diameter and 1⅜ inches thickness, laid in 1886, had borne, for fifteen years, a head of 75 feet of water. The sections of the pipe were 6 feet 3 inches long, and the iron skeleton was formed by 30 longitudinal rods, ¼ inch in diameter, one interior spiral of $\frac{5}{32}$ inch wire and one exterior spiral of ¼ inch wire.

On the 2d of February, 1901, 16 feet of this conduit were taken up. The tubes were found in a perfect state of preservation; the steel did not show the slightest trace of oxidation; the adhesion of the steel to the concrete, despite the slight thickness of the pipes, was such that it could be separated only by heavy blows from a sledge hammer.

at the same distance from the neutral axis. This has the same effect, on the moment of resistance of the beam, as if we had added to the lower part of the section an area of concrete having fifteen times the area of cross section of the steel rods (Fig. 3). This will at once be recognized as the section which, in rational design, is given to cast-iron girders; but the great difference is that, in our case, we get a very considerable increase in strength of section with only a very small increase in weight. The more steel we imbed, the less will be the tensile stresses in the concrete itself and the greater will be the part of the tensile stresses taken by the steel. In fact, in all rational designs the resistance of the concrete to tension is entirely disregarded.

But we have to guard against an excess of steel. If the ideal T section becomes excessively wide at the base, the relatively small compression flange, formed by the concrete, has to take too large a compressive stress, and might fail by crushing. We thus see that,

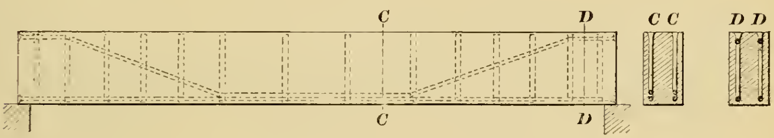


FIG. 5.

in a given section, there can be but one proper proportion of steel to concrete. In building practice there are many cases where the depth of the beam is limited, and where a very high capacity required. In such cases we can further strengthen the beam by imbedding steel rods in the upper part of the section, as well as in the lower part. This gives an ideal T section as shown in Fig. 4. It is clear that we require a less area of steel in the upper than in the lower part, and we must maintain the proper ratio between the moments of resistance of the top and bottom flanges. Otherwise waste of material, or failure of the beam, will follow.

As in any steel and wooden beam we have also to take care of the shearing stresses. The first engineer who grasped the importance of this consideration in connection with the strength of concrete beams was Mr. François Hennebique, and his scientific designs have made him the most successful concrete steel builder in Europe.

The girder (Fig. 5) which he has patented in all civilized countries of the world, can hardly be improved. Its principle consists in imbedding pairs of rods, in vertical planes, in the beam, one

being always straight the other bent upward near the supports, both being united by a number of bent straps or stirrups.

The concrete, in connection with the steel rods, may be regarded as forming queen post trusses, as shown separately in Figs. 6 and 7; the place of the wood being taken by the concrete, and that of the verticals by the stirrups. These stirrups take up also the horizontal shearing stresses, which are greatest at the ends near the neutral axis, and for this reason they are placed close together near the supports (Fig. 5).

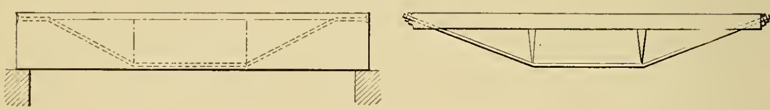


Fig. 6.

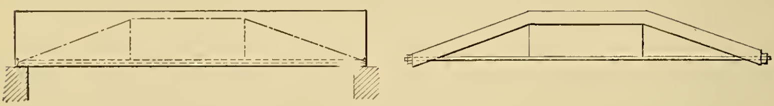


Fig. 7.

Fig. 8.

Numerous tests, made by Mr. Hennebique, with girders with and without stirrups, showed the great gain in strength which results from their use.

It might be objected that we rely on the bond of the steel with the concrete; and that yet, in the most vital part of the beam, namely in the center, the concrete of the bottom flange will first fail when the beam is overloaded, and destroy the bond. This will surely happen, pieces of concrete may even drop out and lay the rods bare; but that is also where the real truss action of this combination commences, in which case we need the bond in the center no longer; the steel rods will be strained in a much higher degree than before, the beam will very appreciably deflect, and at last failure of the beam will follow, either through breaking of the rods, through crushing of the concrete, or through simultaneous failure

of both. But the dropping out of pieces of concrete long before half of the ultimate capacity of the beam is reached gives a timely warning, such as occurs neither in steel nor in wooden beams.

The theory of concrete-metal construction is at least as well known as that of steel beams; in fact, the successful builder in concrete-steel will guarantee his work with greater confidence than can the structural steel works.

But economy and safety are attained only through scientific design, and the greatest calamities would follow if such structures were designed and built by so-called practical men.

One of the earliest applications of concrete-metal was in the construction of fireproof floors. Let us assume that we have to cover an area, a b c d (Fig. 8), by a fireproof floor. In

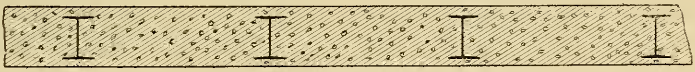


Fig. 9.

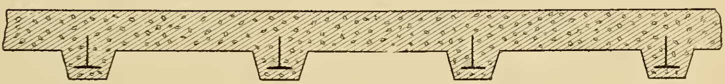


Fig. 10.

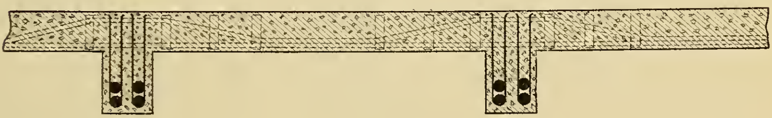


Fig. 11.

simple concrete floors we use steel beams, spaced 4 feet apart, and the whole is filled with concrete, as shown in section in Fig. 9. It was soon found that these floors could carry a slightly greater load than that indicated for the beams alone, and that a more economical floor could be constructed by using T sections instead of I beams and placing them lower (Fig. 10). A similar floor was used in the building of the Citizens Savings and Loan Association in this city, only that T sections of special shapes were employed. But Mr. Hennebique went farther. He substituted rods (Fig. 11) for the T's, a shape which is very easily procured in the market, and, especially to-day, at nearly half the cost of the T's. The girders, corresponding to the steel beams in Fig. 9, are substantially the same as shown in Fig. 5. The slabs, between the girders, form a continuous beam, therefore tensile

stresses are set up also above the girders. These are taken care of by horizontal rods at the bottoms of the slabs, and by bent rods approaching the top fibers over the supports. The whole floor forms the compression flange of this composite girder, while the rods form the tension flange; and the result is that we get a moment of inertia 80 to 100 times greater than that of ordinary steel beams; and, as the ratio of the moduli of elasticity is only 1:15 we see that the Hennebique floors must be at least six times stiffer than steel girder floors.

In this connection I may cite a very interesting experiment, made by the Engineering Department of the Orléans Railroad at their Austerlitz station in Paris. A Hennebique floor, figured to carry a machinery load of 280 pounds per square foot, of a span of about 16 feet, was subjected, for a length of 17 feet, to a load of 420 pounds per square foot. The maximum deflection was $\frac{1}{8}$ inch, without any permanent set. In order to compare the resistance of this floor to shocks, with that of steel girder floors, this floor and a floor of the Quay d'Orsay station, built for the same purpose and of the same span, but consisting of I beams and brick arches, were subjected to the blows of falling weights. The dead weight of the Hennebique floor was 60 pounds per square foot, that of the other 96 pounds per square foot. A weight of 110 pounds, falling from a height of $6\frac{1}{2}$ feet, produced, in the steel and brick floor, vibrations of an amplitude of $\frac{5}{32}$, $\frac{5}{32}''$ lasting two seconds, while a weight of 220 pounds, falling from a height of 13 feet on the Hennebique floor, caused a maximum vibration of only $\frac{1}{32}$ of an inch, lasting $\frac{5}{7}$ of a second. Thus, twice the weight falling from twice the height, caused only one-fifth of the deflection, with vibrations lasting only a third of the time.

This is of enormous advantage in bridges, and especially in factory buildings, not only because the lives of such structures are threatened by vibration, but also because freedom from vibration preserves the tools and makes better work possible.

The high price of steel, the long delays in deliveries of steel structural work, the difficulty (and often the impossibility) of securing economical sections, suggest the use of concrete-steel in the construction of wholly fireproof buildings.

Whether office buildings, apartment houses, residences or factories are to be built by the Hennebique system, the skeleton principle of construction is strictly followed.

If concrete walls are used they are strengthened by rods, and rarely exceed six inches in thickness. The columns consist of four or more rods, connected at short intervals by flat bars, and the

whole is imbedded in concrete. The rods (Fig. 12) are placed in the periphery only, thus giving the maximum radius of gyration and being in position to take any tensile stresses. The connections between the columns and the girders and beams are effected by ample brackets and are monolithic; and, as the floors are six times stiffer than steel girder floors, the stresses, due to eccentric loading, are nearly one-sixth as great.* The columns can be so designed as to suit any exigency. Recesses can be formed for gas and water pipes and electric wiring; brackets can be provided for

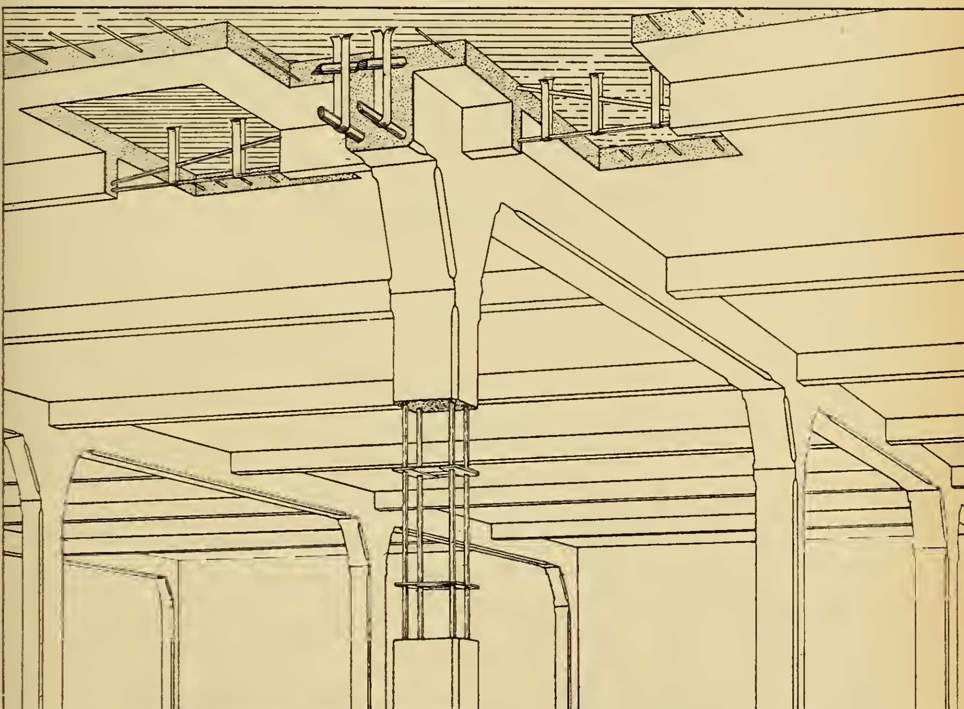


FIG. 12. GENERAL VIEW OF COLUMNS, GIRDERS, BEAMS AND FLOORS.

transmission shafts, electric traveling cranes, etc. . . . The diameters of these columns are only from 1 to 2 inches greater than those of steel columns without fire proofing; but for theaters and other architectural purposes they allow of a considerable reduction in width.

Hennebique columns were subjected to a severe test by the authorities of the last Paris exhibition. The Palais de Costume was entirely built on the Hennebique system. The columns were 20

*See Handbook written by the author for Homan & Rodgers, London.

feet apart, and of such small diameter that the engineers doubted their resistance to eccentric loading, and applied a load of sand weighing 150 tons, or one and a half times the load for which the columns were calculated, in alternate panels of two stories (Fig. 13). The deflection of the columns could hardly be measured, and was a minute fraction of $\frac{1}{32}$ of an inch.

A notable economy is obtained in the use of armored concrete for foundations. The ordinary methods, heretofore in use, can be described by saying that enormous masses of either concrete or steel beams were buried in the ground, making expensive excavations necessary, and cutting into the hard crust which generally overlies the yielding stratum. Hennebique's column footings consist of a layer of concrete a few inches thick, in which are imbedded steel rods in the two main directions (Fig. 14), and a

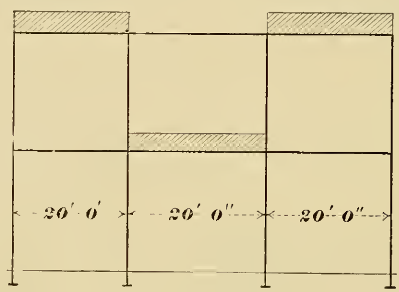


FIG. 13.

monolithic truncated pyramid connected with the column they support. Such a footing may be considered a girder affected by uniformly distributed loads in an upward direction, and a nearly concentrated load acting downward in the center. These forces tend to bend the pyramid in the two main directions, and this tendency is effectually resisted by the concrete in compression and by the rods in tension. The largest of these footings thus far constructed has a side of about 70 feet.

Where pile driving is necessary concrete-steel piles are driven into the ground, and the columns are directly connected with them.

These piles are formed in molds, and the concrete is strengthened by steel rods of suitable dimensions, connected at short intervals by stirrups (Fig. 15). At its lower end the pile is armed with a pointed shoe with side plates, the ends of which are turned in, so as to lock the pile securely in place. The head of the pile is of less width than the body, allowing a clearance between the heads of two adjacent piles. In order to insure uniform blows

from the ram in the process of driving, and to prevent injury to the pile, the head is protected by a cap of cast steel and closed at its lower end by a clay ring held by a plug of hemp or spun yarn. This cap is previously filled with dried sand. A very regular cushion is thus formed on and all around the head, which cushion distributes the pressure in an absolutely uniform manner. This arrangement renders it permissible for the iron rods to project beyond the head of the pile, so that, in case of need, they may be connected with other parts of the structure or bent into hooks for convenience of handling.

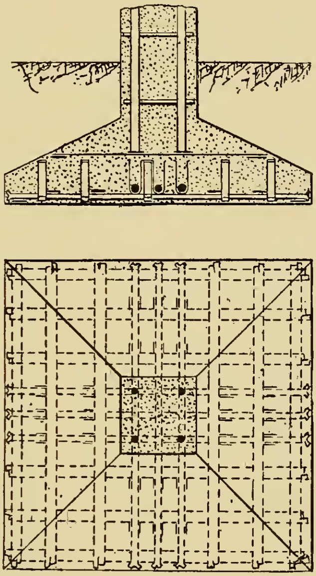


Fig. 14. Column Footing.

The sheet piles (Fig. 16) are strengthened by four rods, connected by wire clamps, which, in their turn, are cross-tied by flat irons. At the lower end we have again a shoe, and the head is again of less width than the body, allowing room for the insertion of a cap. About 6 inches above the shoe on the longer of the narrow sides a projection, *m*, is formed, while the remainder of both narrow sides is grooved for the entire length. The projection on one of the piles slips into the groove of the next pile in ramming.

A special arrangement is provided to insure the desired direction of driving. An iron pipe which fits the groove of the sheet pile last driven, and that of the pile which is being driven, con-

nects, by means of a hose, with a pump or water tank. This pipe serves also as guide, and the water forces out the sand which might jam the grooves, thus facilitating the driving of the pile. Once the pile is down to the desired depth, the pipe is withdrawn, cement

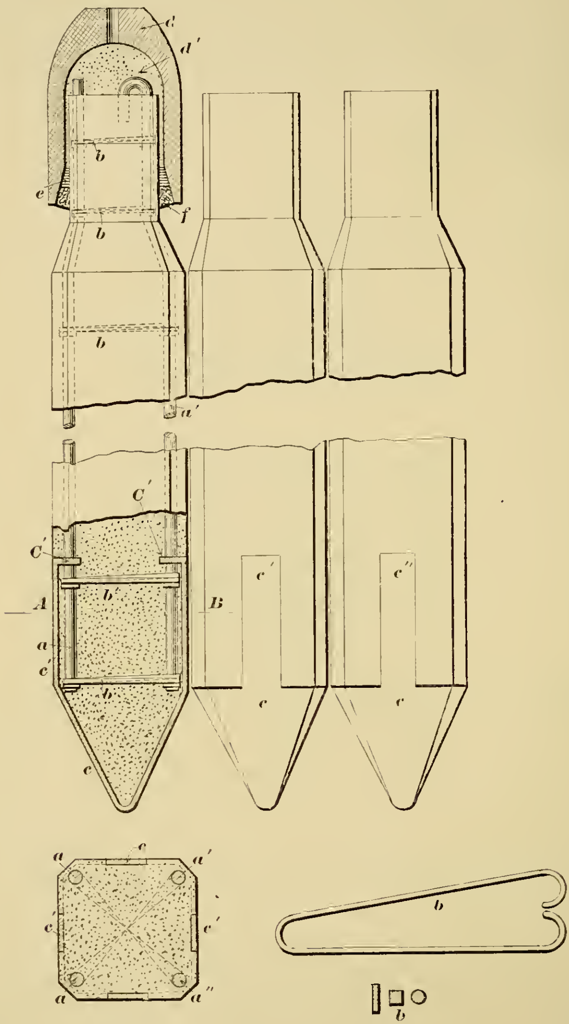


FIG. 15.

is run between the grooves and a perfect water-tight joint and wall are established. Tongue and groove joints are also sometimes used.

These piles are somewhat more expensive than wooden ones, but are practically indestructible and of enormous resistance to

bending. They are affected neither by the rise and fall of ground water nor by sea water, nor can they be attacked by teredos, which, in certain parts of the globe, destroy wooden piles in a very short

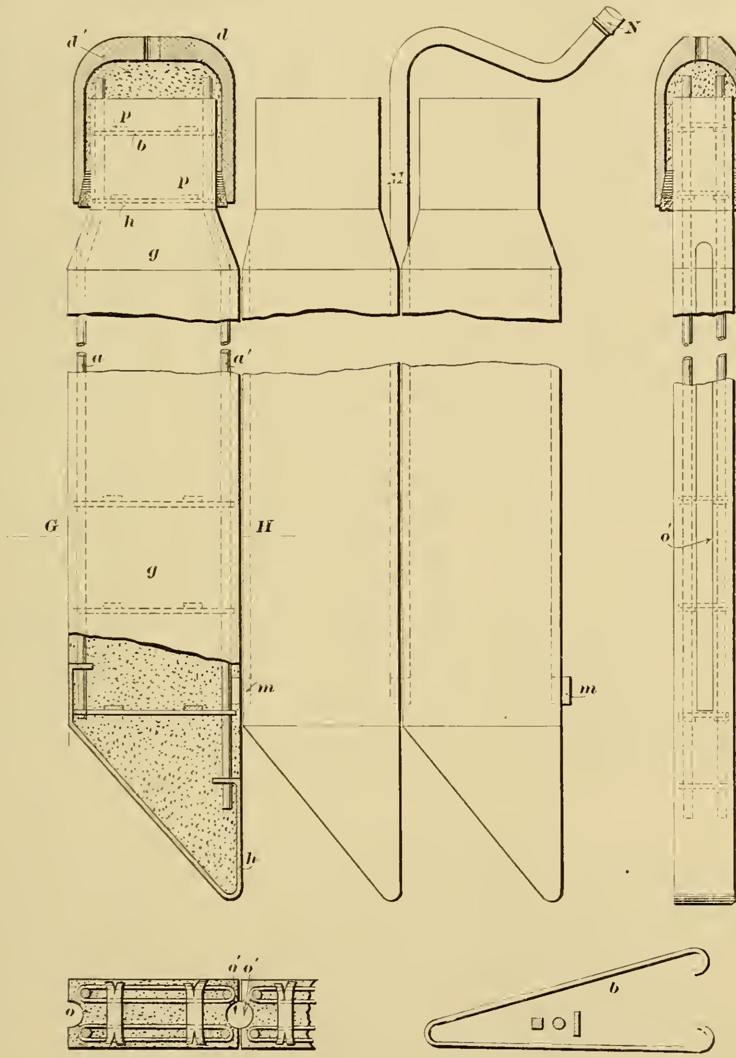


FIG. 16.

time. What an ideal member in the construction of sea walls, breakwaters, recreation piers, etc. . . . !

I have now described in particular the different elements which compose a building designed on the Hennebique system; but it yet

remains to prove their resistance to fire. Of the many tests which Mr. Hennebique and various European governments have made on buildings of his design, I will describe the fire test of a two-story pavilion at the Exhibition of Ghent, in Belgium, in 1899. This pavilion, measuring 20 x 15 feet, was built entirely of ferro-concrete, and the windows and doors were provided with Siemens wire glass. In all, two tests were made. In the first test the second floor was loaded with 300 pounds per square foot, or one and a half times the load for which it was designed, and a deflection of $\frac{1}{3000}$ of the span was produced. On the 9th of September the lower room was filled with about 220 cubic feet of wood and coal. This material was sprinkled with petroleum and set on fire. The conflagration lasted one hour, and produced a temperature of about 1300° F. The walls were red hot on the inside; yet, notwithstanding that their thickness was only $4\frac{3}{4}$ inches, the hand could easily be held on the outside without experiencing any discomfort.

The temperature of the second floor increased only 4°, which means that no mercantile product whatsoever would have suffered damage. The deflection of the floor increased to $\frac{9}{16}$ of an inch, but two hours after the extinction of the fire was diminished by half an inch, so that under a very heavy load the permanent deflection resulting from the fire was scarcely perceptible.

In order to prove that an armored concrete floor, which had been subjected to fire, was still capable of bearing the same loads as before, Mr. Hennebique made a new test on the 28th of September; this time loading the floor with 400 pounds per square foot, or double its intended load. When the 300 pounds mark was reached the deflection was found to be precisely the same as before the first test. At 400 pounds per square foot the deflection was only $\frac{1}{8}$ of an inch.

The lower room was completely filled with wood and coal, the upper room partially filled with the same materials, and the roof was loaded with 200 pounds per square foot. At six minutes past four the fire was lighted on both piles and lasted until half past six. The fire played so fiercely against the sides and ceiling that the plastering of the latter was calcined, and the wire glass of the windows and doors melted.

The building was momentarily forced out of shape (expanded), but showed no cracks and only very fine fissures, which in no case let the hot air escape. Again the contact of the hand with the outside of the walls could easily be endured. The deflection of the second floor reached a maximum of $\frac{3}{4}$ inch at 20 minutes to six; after this time no further increase could be observed.

At half past six, when, after continual firing, no change in the state of the building could be detected, the commission agreed to extinguish the fire, which was done by directing a stream of water from a hose against the walls and ceiling and afterward against the coal piles.

When, on the following day, the fire authorities examined the building, it was found that the conflagration had not injured the general structure in any way. There was no permanent set in the floors and the few fissures caused by the expansion were completely closed. A series of pyrometers indicated a temperature of 2200° F.

Lime kilns, constructed entirely of concrete, dispensing with fire bricks and steel shell, have endured for years a temperature of 2200° to 2500° F.

From every point of view armored concrete buildings are superior to those of any other type. They are monolithic; settlement of the ground is properly transferred and equalized by means of their enormous stiffness; they consist of practically one material, and variation of temperature cannot produce unsightly cracks; they become stronger with age, concrete forming an artificial stone better than the best stone which ever came from a quarry; the buildings are cool in summer and warm in winter.

Considering, moreover, the facility with which the materials can be procured, so that only a few months are needed to erect the largest building, together with the surprisingly low cost, it must be evident that the time of steel skeleton buildings, with all their flimsy lug and bracket connections, their insufficiently protected columns and their high cost, is past and that they must give way to a far superior type which will be the construction of the twentieth century.

The photographs show the great range of work done by Mr. Hennebique, including factories of all kinds, as flour and spinning mills, ice factories and foundries with heavy traveling cranes, the runways being also of concrete steel, smoke stacks, storage houses and power blocks, apartment and office buildings of fifteen stories in height, department stores, theaters, museums, banks and fireproof vaults, domes and churches, markets, railroad stations and small switch houses, free supporting staircases, floors of any practical span (those in the Grand Palace of Fine Arts in Paris having a span of 33 feet and a cantilever of 11 feet), exhibition buildings, coal bins, water towers, grain elevators, power and irrigation canals, tunnels, retaining walls, wharves and piers, and (last, but not least) bridges.

Armored concrete bridges are indestructible, requiring no supervision or repairs. If of moderate span, they are cheaper than steel bridges and have always a fine architectural appearance.

Through the columns of *Engineering News,* of this year, we have learned the disastrous results of adopting the so-called "Leg bridges" for country roads. They consist of steel piles, forming the abutments, and plate or lattice girders carrying the floors, the two being connected by brace angles. They failed by scores. A few concrete-steel piles and a 4-inch curtain wall as abutments, a few

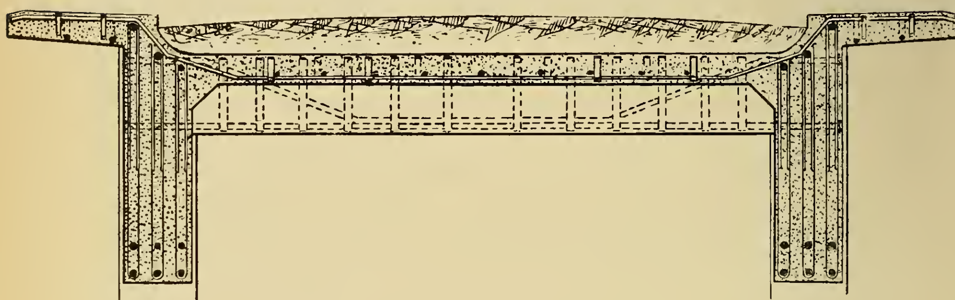


Fig. 17. Cross Section of a Bridge.

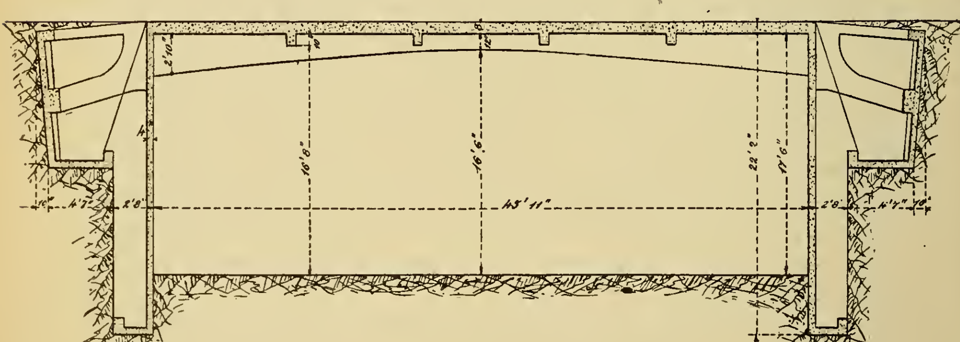
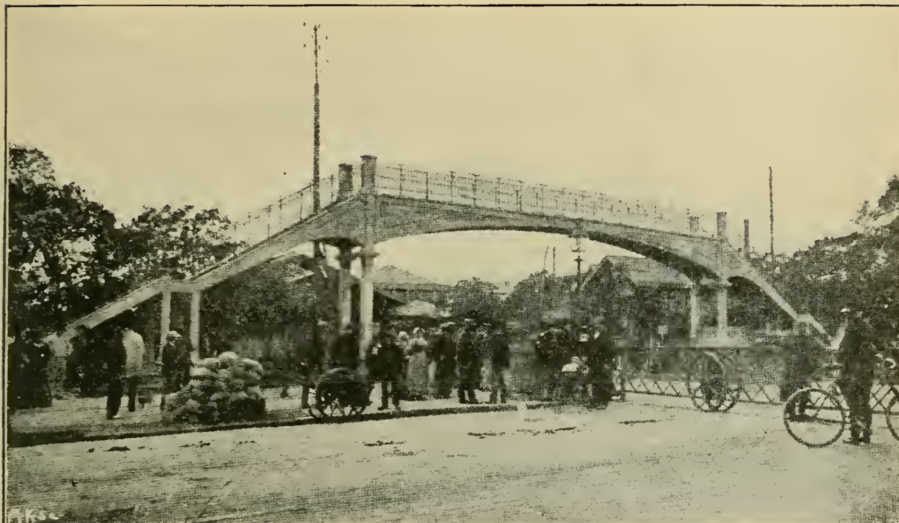


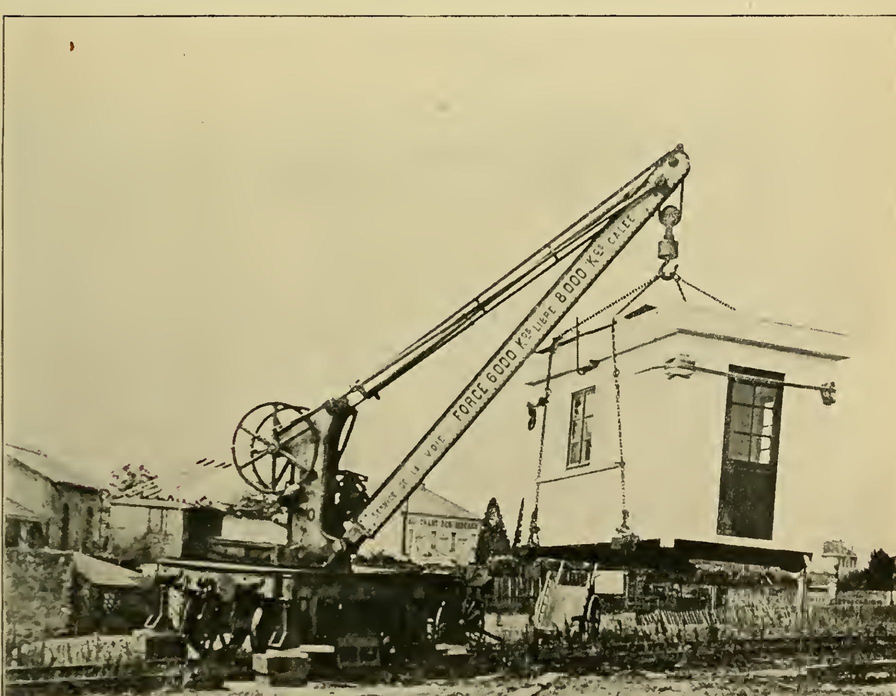
Fig. 18. Longitudinal Section of Bridge over the Quai Debilly, Paris.

armored concrete piles mid span and a concrete steel floor, monolithically connected with these piles, will make a bridge as cheap as a "Leg bridge," but far better and indestructible.

Fig. 17 shows a typical cross section of a ferro-concrete bridge of moderate span. The floor of the roadway and the cantilever sidewalks form the compression flange, while the rods in the bottom of the girders proper form the tensile flange of a huge girder, and, for the same reason as in floors, this type of bridge is much stiffer than are plate girder bridges. The cross girders, roadway and sidewalks are all built of ferro-concrete.



FOOTBRIDGE OVER RAILROAD, LORIENT, FRANCE.



TRANSPORTABLE GUARD HOUSE FOR ORLEANS RAILROAD, FRANCE.

Fig. 18 shows a longitudinal section of the bridge of the Quai Debilly, in Paris. This is composed of twelve armored concrete

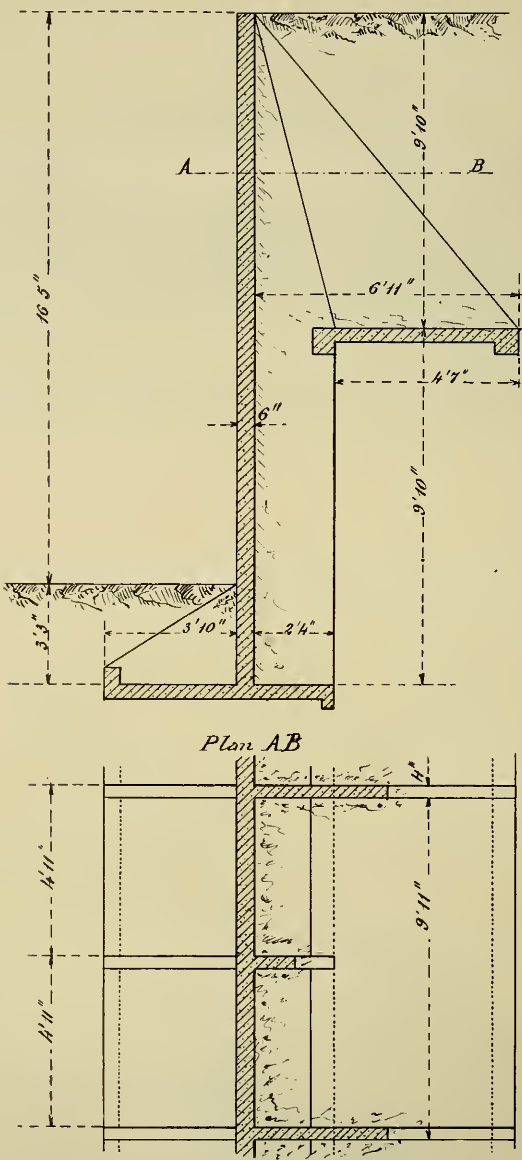
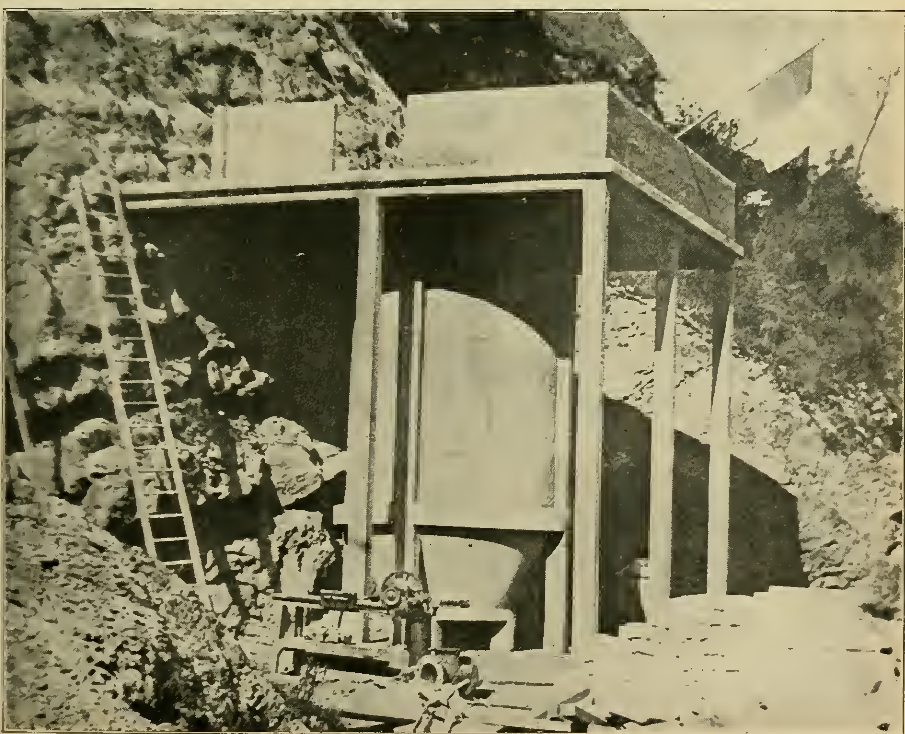


FIG. 19. RETAINING WALL OF THE QUAI DEBILLY, PARIS.

arches of 46 feet span, placed about 8 feet apart. The rise is 2 feet or $\frac{1}{23}$ of the span. The floor for the roadway and sidewalks

Bridge over the River La Vienne at Chatellerault, France.



Limekiln, Luzech, France.

varies in thickness, and is supported by armored concrete cross girders and about 100 feet wide. The abutments and foundations, also built of armored concrete, are of special design.

Fig. 19 shows a section through the retaining walls. A curtain wall, 6 inches thick, is connected by means of deep ribs with a

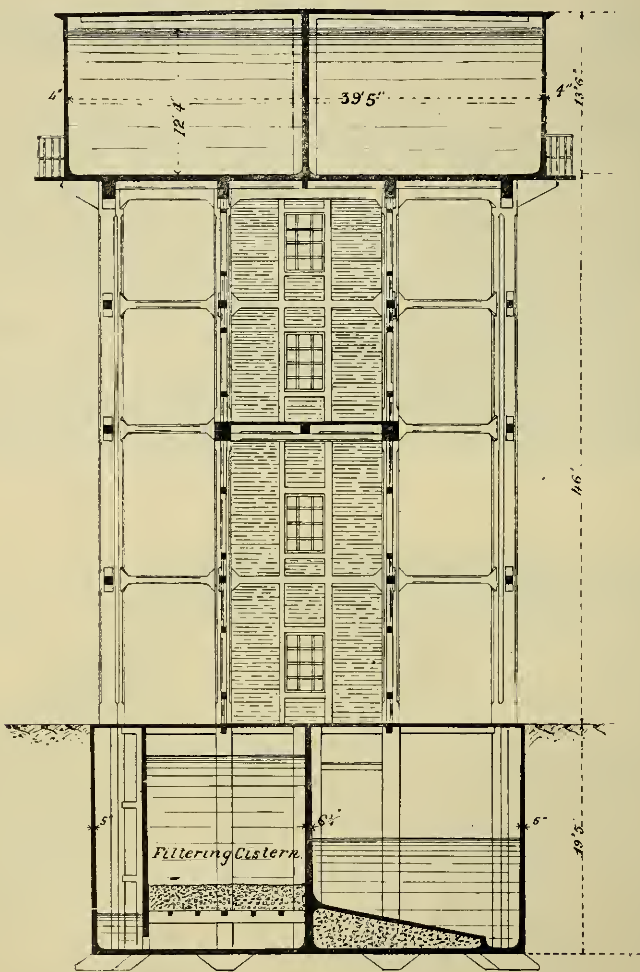
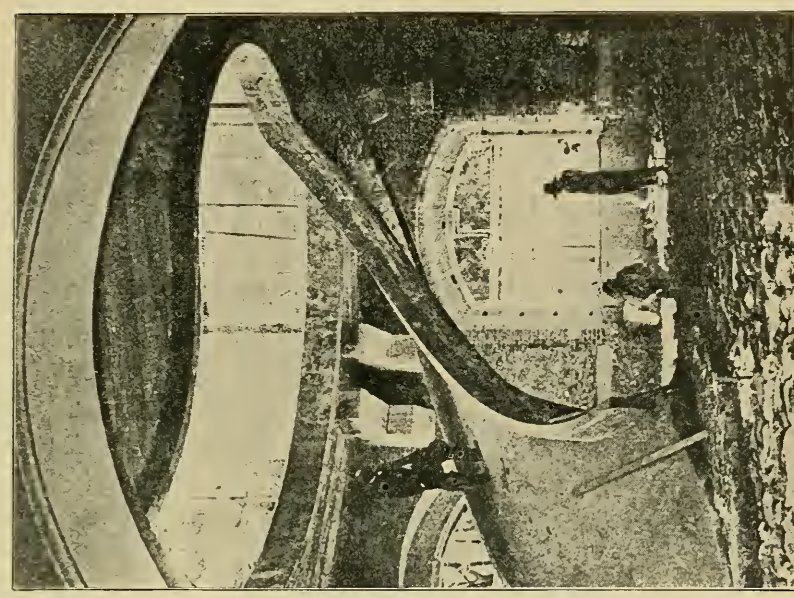


FIG. 20. WATER TOWER AT BILLANCOURT, FRANCE.

platform at mid-height. This platform supports a load of earth 10 feet deep, which in the simplest manner prevents overturning of the walls. The bridge was calculated for a uniform load of 123 pounds per square foot, and for a train of 10-ton wagons. It was tested on February 6, 1900, by a uniform load of 123 pounds per square



Staircase in the Palace of Fine Arts, Paris Exposition.

Coal Bins, Mines of Lens.

foot, 248½ tons in all, and gave a maximum deflection of only ¼ inch or $\frac{1}{2154}$ of the span.

A second example is the bridge of Chatellerault, over the river Vienne, in France. This is the greatest work of art that has been constructed on the Hennebique system. The total length of the bridge is 443 feet, and consists of three spans, the end spans of 135 feet with a rise of 13 feet, and a central span of 164 feet and a rise of 15 feet 8 inches. Four arched ribs in armored concrete, 20 inches deep, support the floor of 25 feet width by means of 8 x 8 inch posts. The sidewalks partly overhang. The total thickness of the bridge at the crown is only 28 inches.

It will be noticed that this bridge is designed on the same lines as would be expected in steel-arch bridges, such as the Washington bridge in New York; and the lightness of this structure explains its surprisingly low cost of hardly $35,000.

The foundations of the bridge were easily laid, the calcareous rock being found at 5 feet below low water mark. The piers and abutments consist of heavy ribs, corresponding to the four arched ribs and connected by curtain walls 5 inches thick, to give them their external shape and stiffness. They were filled with low grade concrete of hydraulic lime.

The bridge was calculated for the passage of two 16-ton wagons, and for a uniform load of 100 pounds per square foot. The concreting of the bridge was done in less than three months, and five weeks later the centering was removed. The tests with stationary loads were made in the following manner: each span was loaded over its total length, then on each half, then on its central part, with moist sand at the rate of 165 pounds per square foot on the roadway and 123 pounds on the sidewalks.

The official report of the test says:

The maxima of the deflections were ¼ inch for the arch of the left shore, $\frac{7}{32}$ inch for the arch of the right shore, and $\frac{13}{32}$ inch for the central arch, that is, $\frac{1}{7300}$ and $\frac{1}{5000}$ of the spans respectively. The specifications allowed deflections of $\frac{9}{16}$ inch for the 135-foot span and of 2 inches for the 164-foot span. After removing the loads no permanent deflection could be detected.

The moving test load was composed of:

First. One 16-ton steam roller;

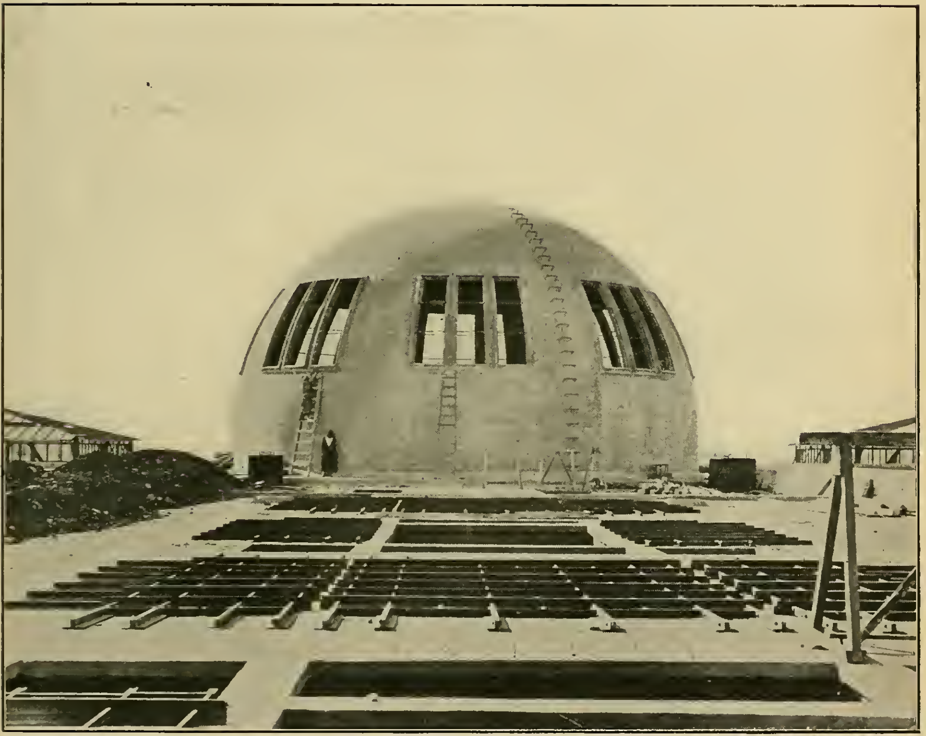
Second. Two two-axled wagons weighing 16 tons in all;

Third. Six single-axle wagons weighing 8 tons in all;

making a total of forty tons moving simultaneously over the bridge, the sidewalk of which had to carry also 80 pounds per square foot. The maximum deflection reached was less than $\frac{1}{9000}$ of the span.

Furthermore, 250 infantrymen were made to cross the bridge, first in ordinary marching order, then in double quick time. Also, strips of wood were strewn over the roadway in order to produce shocks when the steam roller passed over them.

But the most remarkable feature shown by these tests was that the three arches were in fact continuous, so that the load which caused a depression in one arch produced at the same time a rise of the other arches, an evident proof that ferro-concrete structures are monoliths.



DOME OF THE MUSEUM OF THE EGYPTIAN ANTIQUITIES AT CAIRO, EGYPT.

You will be surprised at the numerous applications of the Hennebique system. The explanation is simple. The inventor has been able to interest in his system a great many engineers, architects, practical and scientific men, who have imparted to him their ideas and have become his collaborators.

Europe is to-day in the lead of concrete-steel structures. Let us hope that the enterprising American spirit will, as energetically as formerly with regard to steel, take up and lead in this, which is undoubtedly the greatest industry which we have to expect in the twentieth century.

INORGANIC AND ORGANIC SOURCES OF CONTAMINATION OF WATER SUPPLIES.

By E. Starz, Member Montana Society of Engineers.

[Delivered before the Society, January 10, 1901, at the Fifteenth Annual Meeting.*]

Pure and wholesome water is one of the first necessities for a prosperous community. Since scientific research has revealed the fact that certain diseases are spread broadcast through drinking water, great interest has been aroused among the water-consuming public, as well as among those who are in charge of the water supplies. Throughout this country and abroad laws have been enacted to minimize the contamination of water sources, and nothing has proved more beneficial, or has paid back better, than the strict enforcement of such laws. The fact that in cities with a good sanitary water supply the mortality is generally less than in those not so blessed should be sufficient to arouse general interest.

The engineer in charge of a water supply is as deeply interested in the quality of a water supply as in its quantity, and to-day he must work together with the chemist and microscopist if he will command the position he is endeavoring to fill.

The fact that a water supply is contaminated with organic or inorganic matter is not sufficient alone; it is equally necessary to know the exact nature of the polluting material.

Biological examination of water was introduced only a few years ago, but it has already proved of great value, and the interpretation of results of a water analysis is greatly facilitated when undertaken in connection with the micro-biological findings.

The Sedgwick rafter method of concentrating and quantitatively estimating the number of suspended organisms in one cubic centimeter of water is of the greatest help to the biologist and chemist.

Another important step in determining contamination due to small organisms is the method of growing bacteria in certain culture media and transplanting or inoculating the growth from one tube to another until a pure culture of the germ is isolated, by means of which all the tests for identification can be made and the specific atomic organism definitely recognized. The quantitative estimation of the number of germ colonies in one cubic centimeter of

*Manuscript received June 26, 1902.—Secretary, Ass'n of Eng. Socs.

water has also proved valuable; but, of course, the differentiation of the quality of certain germs—that is, whether or not they are disease-producing germs—is of more practical value.

Thus science has found methods and processes which facilitate the work of investigation and make it possible for the engineer, chemist and biologist to apply remedies to a polluted water system or to prevent altogether its impregnation with foreign matter.

The consumer of drinking water demands that it be clear, odorless, tasteless and colorless, and, while these properties do not demonstrate that the water is free from polluting substances (because the most harmful of such substances escape coarse physical observation), the demand shows, nevertheless, that the esthetic point is not lost sight of. On the other hand, of course, a turbid water need not necessarily be dangerous to health, but it is repulsive, owing to its disgusting looks. Waters having odors and bad taste are objectionable and, as a rule, suspicious, because they generally indicate that the water is rich in dissolved organic substances, and such a water furnishes a very good substratum for the multiplication of germs, pathogenic as well as harmless.

Our water supplies generally comprise (1) surface water, such as spring, river, stream or lake water; (2) subsoil water, such as we have in wells, and (3) deep or artesian well water.

Of the three sources, the most common and important in our Western states are surface and subsoil waters, and, of the former, river, stream and spring water. Wells represent, as a rule, the subsoil water.

All streams, rivers and springs used for public water supply are exposed to contaminating influences, the possibilities of contamination increasing with the length of the flow of the stream and with the number of habitations along its borders. The same is often the case with wells, especially when so situated that surface drainage can easily gain access to them. Below I shall give some facts from which it will be seen how dangerous to health may be a poorly constructed and badly located well, receiving percolating refuse and waste water from surrounding houses and stables. A heavy rain or melting snow might convey to a well obnoxious material, which has lain inert for months, and create a severe outbreak of disease. The fact that nothing of that kind has happened with the water in the well during the last five or ten years does not remove the possibility that to-morrow infection from surface drainage may take place, with disastrous results. Properly constructed wells, remote from stables, human habitations and other sources of pollution, deliver, as a rule, wholesome, potable water.

Contamination of drinking water comprises all foreign substances not essentially found in natural waters, but the sources of contamination are manifold and of different character, and we may classify them as follows:

I. Inorganic sources of contamination.
- (A) Soluble.
- (B) Insoluble or suspended matter.

II. Organic.
- (A) Living organic matter,

  of { a. Vegetable / b. Animal } nature.
- (B) Dead organic matter.

INORGANIC SOURCES OF CONTAMINATION OF WATER SUPPLIES.

Under this head come principally industrial and mining enterprises, the waste products of which are sometimes allowed to mingle with the water supply of a community, rendering it impotable. Stamp mills, concentrators and placer mines furnish, as a rule, most of the insoluble (suspended) inorganic polluting matter, while manufacturing establishments, mines, cyanide plants furnish dissolved inorganic elements. Clay, talcum (silicate of magnesia), sulphate of lime, when very finely divided, and mixed, for instance, with the water of a stream supplying water for drinking purposes, subside very slowly, rendering the water milky and turbid.

While these substances have no physiological action upon the human system, they may, when present in large quantities and ingested into the stomach, cause trouble by mechanical action. Smelter slacks, when in very fine condition, may become obnoxious when mixed with water used for human or animal consumption. They consist, as a rule, of iron, arsenic, sometimes copper, zinc, antimony and traces of lead in combination with sulphur, according to the composition of the ores used in the smelting operation.

These sulphides are practically insoluble in water, and they retain some of their component poisonous elements until they are exposed in moist condition to the atmospheric oxygen and carbonic acid, when oxidation and the formation of more soluble elements take place. The latter may subsequently be washed into the water with the next rain or the melting of snow, and thus lead to occasional poisoning of men and animals. Placer mining is sometimes a source of inorganic contamination, if the waste water, as a rule heavily loaded with fine suspended earthy particles, has opportunity to gain access to a water supply.

Most of the above-mentioned sources of pollution render a water supply objectionable, mainly through the unsightly appearance they give to it.

Soluble inorganic contamination comprises all those elements which are not a component part of natural waters and which have a decided action upon it, affecting, for instance, its taste, odor and color, or which possess distinctly poisonous properties when introduced into the human system.

As an example, I might mention the astringent taste which certain iron salts communicate to water, and occasionally water sources in mining districts have suffered through the admixture of iron which originated from the iron pyrites occurring in the mines.

The iron pyrites, exposed to moist atmosphere, decompose in about the following manner: A part of the sulphur of the pyrites is oxidized to sulphuric acid, which now acts upon the remaining pyrites or sulphide of iron, decomposing it, so that hydrogen sulphide is produced on the one hand and on the other a soluble sulphate of iron. The latter would soon undergo oxidation to ferric salts were it not for the reducing action of the hydrogen sulphide, prohibiting at this point the passage of the ferrous salt into the ferric state.

As soon, however, as the ferrous sulphate is carried away with the water, and no reducing action interferes any longer with it, oxidation takes place and goes on until most of the ferrous salt is precipitated as an insoluble hydrated sesquioxide of iron, which is of a yellow (rusty) color, and subsides readily.

Other and more serious cases of contamination with soluble inorganic substances are on record. For instance, lead poisoning is caused by leaden water pipes and by springs flowing through extensive lead deposits. Copper, zinc and arsenic also sometimes render water unfit for domestic use.

Lead, copper, arsenium and zinc are considered dangerous in any amount present in a drinking water supply.

SOURCES OF ORGANIC CONTAMINATION.

Living organic substances, which include the pathogenic bacteria, have caused more annoyance than probably any other source of contamination.

The pathogenic or disease-producing bacteria are the most dangerous, and hence most unwelcome, parasites in a water supply. An insignificant creature, a cell scarcely discernible under a microscope, may become the slayer of thousands of persons. It has

caused epidemics of cholera and typhoid fever which have decimated population and have cost communities enormous sums of money.

What are bacteria?

Every second during life we make the acquaintance with bacteria or germs, but it is the privilege of only a few to see them and to watch their doings while they are alive. Bacteria, cocci, bacilli or microbes are one-celled microscopic organisms, belonging to the

1, Bacillus of Typhoid Fever; 2, Bacillus of Asiatic Cholera; 3, Bacillus of Coli Communis; 4, Cocci—Staphylococcus and Streptococcus.

lowest form of plants. They are destitute of chlorophyll, the green coloring matter of higher vegetation, and are either saprophytes (living in the external world at the expense of dead organic matter) or parasites (invading living organisms). They live at the expense of complex organic substances, which they reduce to the condition of simple mineral compounds. Microbes are found in the atmospheric air, waters, soil, food, the living organism, clothing,

dwellings, etc. They propagate or multiplicate by binary division. When circumstances are favorable for rapid multiplication, the individual cells grow in length, and a constriction occurs in the middle transverse to the long diameter. This becomes deeper, and after a time the cell is completely divided into two equal portions, which again divide in the same way. Separation may be complete or the cells may remain attached to each other, forming chains, like the streptococci or articulated filaments. The bacilli divide only in a direction transverse to the long diameter of the cells, but among cocci division may occur in two or three directions.

As already mentioned, germs are present almost everywhere, and, fortunately, most of those found in water, air, rooms, etc., are harmless or not disease-producing, and some serve even a good purpose by producing certain phenomena, such as fermentation and nitrification.

Surface waters are always very rich in germs, the nature of which is extremely variable; the majority are harmless, pathogenic or disease germs being much less frequent. Waters rich in dead organic matter favor the multiplication of germs.

Among the most important disease-producing microbes to be here considered are the bacillus (typhosus eberth) of typhoid fever and Koch's comma bacillus, or the germ of Asiatic cholera. Both have done immense damage to the human race, and in some countries laws have been enacted to prevent the contamination of water supplies with these germs. During the cholera epidemic in London, 1832, 110 out of 10,000 people died in Southwark; in 1849, 121 out of 10,000; in 1854, 154 out of 10,000 succumbed to the disease. The cholera epidemic in Hamburg in 1892 serves as another example of the transmission of cholera germs through water used for domestic purposes.

Typhoid fever is the result of unsanitary conditions brought about by man, and, since our population is increasing in every direction, and the raising of cattle, hogs and domestic fowls is proportionately multiplied, in order to supply sufficient food, there is necessarily a similar increase of waste products, such as human and animal dejecta, vegetable waste and various kinds of refuse products from the kitchen, butcher shops and wash houses, which, in the process of decomposition and decay, are liable to enter our streams and pollute them so as to endanger the health and lives of those who use them as their sources of water supply.

The germs of typhoid fever and of cholera can be conveyed into a water supply in different ways:

First. Through the sewerage of the city.

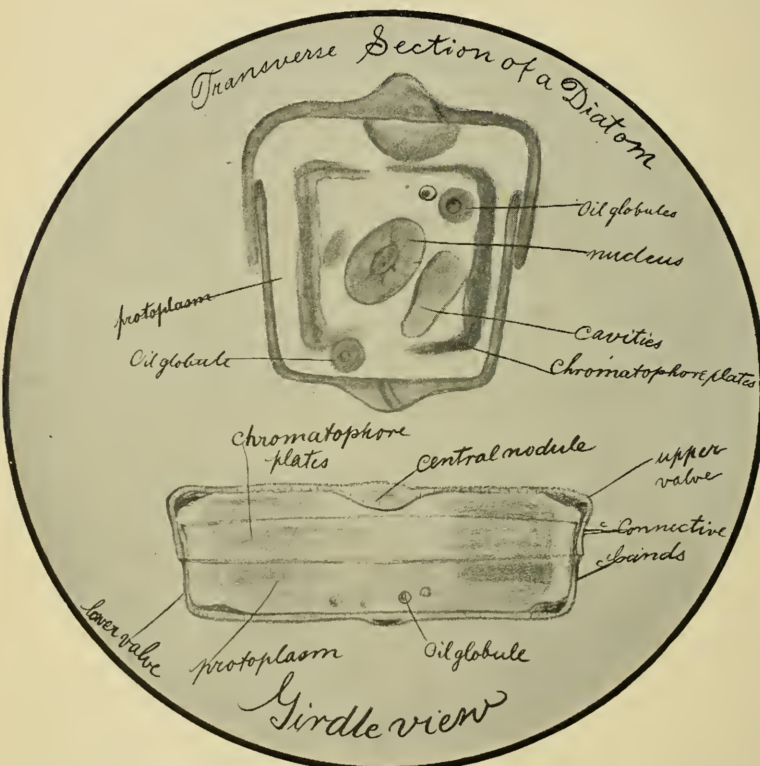
Second. Through being carried into a stream by surface washing from rain and snow.

Third. By being carried down into the subsoil by percolation.

Fourth. By flying insects, birds, etc.

Fifth. By wind and rain.

Almost every year outbreaks of typhoid fever come to our notice, and most of them have their origin in polluted water sources. The bacillus of typhoid fever, voided with fæcal matters, may pass



with the liquids of cesspools through porous soils and thus contaminate subterranean waters. When these waters are used for human consumption, an outbreak of typhoid fever may result. The knowledge of this fact has enabled us in numerous cases to trace the disease to its source and to check its extension.

Pathogenic bacteria preserve their virulence in water for varying periods. The bacillus of typhoid fever retains its vitality for two months; that of anthrax (charbon) for four months, etc.

DIATOMS (*Diatomaceæ*).

Diatoms comprise a class of unicellular cryptogamous plants, with siliceous cell walls and regular markings. The diatom is constructed like a glass box, having a top valve and a bottom valve, on both of which markings are found. The valves are connected by membranes or girdles. There are two of these membranes, one attached to each valve, and so arranged that one slides over the other. Diatoms are found in all shapes, oval, needle-shaped, round, canoe-shaped, triangular, etc., and varying in size from ten mikrons to one mikron. They exhibit movements, and multiply by a process of binary division. While the majority of these organisms are harmless, some of them have given owners of water supplies the greatest trouble by imparting to the water a bad odor and taste. Whipple, in his work on the microscopy of drinking water, says: "Almost all surface waters have some odor; many times it is too faint to be noticed by the ordinary consumer, though it can be detected by one whose sense of smell is carefully trained. On the other hand, the water in a pond may have so strong an odor that it is offensive several hundred feet away."

Between these two extremes one meets with odors that vary in intensity and in character, and that are often the source of much annoyance and complaint. Whipple divides the odors of surface waters into three groups:

First. Odors caused by organic matter other than living organism.

Second. Odors caused by the decomposition of organic matter.

Third. Odors caused by living organism.

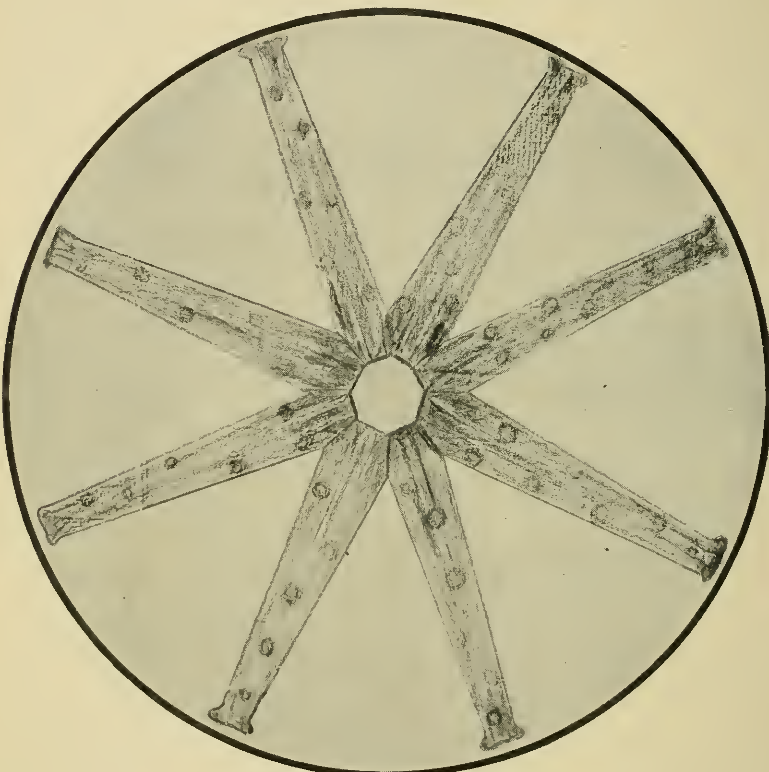
The latter are the most important, because of their common occurrence and of their offensive nature, and because they generally affect large bodies of water, such as reservoirs, etc. Just as nature has provided the skunk, the muskox and some other of the higher animals, and also a majority of the higher plants, such as violets, roses, etc., with odoriferous substances, so has nature not overlooked these minute diatoms. It was formerly supposed that the odors transmitted to the water by certain diatoms were the outcome of the decay of those organisms, but scientists have found that the odor is innate to them, as is the smell of the violet to that flower. Whether the odoriferous substance is a defensive agent for the little diatom against small animalcules, or whether it serves some other purpose, is a matter yet to be studied.

Asterionella is one of the most troublesome representatives of the diatomaceæ, on account of the very offensive odor it imparts to the water. In 1896 it developed in Ridgewood Reservoir, in Brook-

lyn, N. Y., in great abundance and rendered the water very offensive.

Synedra, another diatom, is occasionally observed in water supplies, and it imparts to them a bad taste, odor and turbidity when present in large numbers, say about nine thousand per cubic centimeter.

Melosira, tabellaria, stephanodiscus are other diatoms which give rise to offensive odors and taste to drinking water.



ASTERIONELLA (*Diatomaceæ*).

Other plants contaminating drinking water supplies by creation of bad odor and taste are found among the schizophytes or cyanophyceæ (blue-green algæ). The most troublesome representative of these is the anabæna, which, probably more than any other organism, has caused trouble with water supplies in different parts of this country.

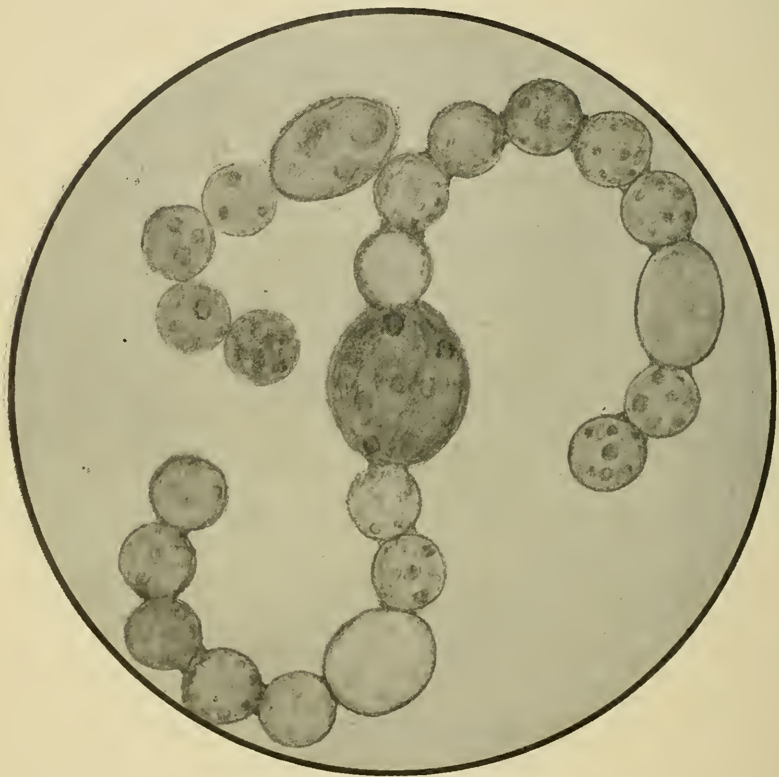
The anabæna flos aquæ is a free-swimming (æruginous) or bluish-green alga, more or less curved, often circinate, with ellipti-

cal heterocysts and globose spores. The diameter of the filaments is four to six millimeters, and that of the heterocysts often eight to twelve millimeters. The plant is surrounded by a gelatinous envelope. The coloring matter is distributed throughout the cells, and consists of chlorophyll and phycocyanin (a nitrogenous body). The plant sometimes multiplies by simply dividing and forming cells, each like the parent cell. Another method consists of forming

CYANOPHYCEÆ.

thick-walled spores which are able to withstand the adversities of temperature and other atmospheric conditions. These spores are the cause of the sudden appearance of the anabæna in reservoirs. They are probably washed into it by a stream or spring and fall to the muddy bottom, where they may remain inactive for a long period, until temperature and other influences favor their germination. Toward June, July, or sometimes earlier, the young plants begin to show their presence, first as minute whitish specks on the

surface of the water, later on forming a scum and at the same time producing a bad smell and taste in the water, suggesting that of mouldy (nasturtium stem) grass which renders the water entirely unfit for use. At this point the water acquires an opalescent appearance, due to the finely divided cells. Upon heating the water the bad odor increases. Jackson and Ellms state that the odor is caused by the breaking down of highly organized compounds of



ANABÆNA.

sulphur and phosphorus, and in presence of large amounts of nitrogen, about 9.66 per cent. According to Whipple, the gas given off during decomposition of the anabæna is composed of:

Marsh gas	0.8 per cent.
Carbonic acid (CO_2)	1.5 per cent.
Oxygen	2.9 per cent.
Nitrogen	12.4 per cent.
Hydrogen	82.4 per cent.

Generally toward September the anabæna disappears, after having seeded the mud at the bottom of the reservoirs with spores, the latter remaining at rest until the following spring, when thermal conditions cause the same process of evolution as in the previous year. From this little pest one of the greatest water systems in the West has suffered for several years past, and, as far as I am aware, all efforts to eradicate it have been fruitless. The only successful

CRENOTHRIX.

way is to shut the infected water supply out. Now, in justice to those in charge of such water supplies, polluted by odor-producing organisms, I will say that they cannot fairly be held responsible for the pollution, and that they are sometimes very unjustly criticised, because they never can foresee the invasion of microscopic organism like the anabæna, and no filtration or other process could restore the water to its original condition. It is a hopeless fight, a battle with disastrous result, because the microscopic organism will

come out victorious, and those in charge, who do their best to relieve their patrons from the stench of the water, have to foot the bills and quit. The Boston and Brooklyn water supplies had to fight the same pest, and monographs about the anabæna and its offensive conduct have been written by the most prominent biologists in the country.

DIATOMACEÆ.

1, Epithemia; 2, Navicula; 3, Struroncis; 4, Cyclotella; 5, Pleurosigma; 6, Survella.

CHLOROPHYCEÆ.

7, Raphidium and Closterium; 8, Cosmarium; 9, Scenedesnius; 10 and 12, Polyedrium; 11, Pediastrium; 13 and 14, Protococcus.

In the same class belong a few others which sometimes give trouble to a water supply. They are chroococcus, glœocapsa, cylindro-spermum, scytonema, rivularia.

Among the schizomycetes are also a few very obnoxious organisms which in several cases have done harm to water supplies. The main perpetrator of this class is crenothrix, which created a water calamity in Berlin in 1878, and also in Rotterdam in 1887. Creno-

thrix causes trouble by growing almost everywhere in a water system, on the walls of reservoirs and in the filter galleries and distribution pipes, the latter of which it may entirely fill up. It is a small filamentous plant, the cells of which are not much larger than the bacteria. Its filaments have gelatinous sheets, colored generally brown by a deposit of ferric oxide. It grows in tufts, and its filaments are sometimes interwoven like felt.

Beggiatoa is another representative, mostly found in waste waters and sewage, and its presence in a water supply indicates very

MUCOR (*Fungi*).

probably sewage pollution. It presents almost colorless threads, containing numerous dark sulphur granules. The filaments have frequently an active oscillating movement.

Fungi (moulds) are sometimes found in well water of doubtful purity. They are flowerless plants, destitute of chlorophyll and starch, and unable to assimilate inorganic matter. They consequently live as saprophytes or parasites; that is, they live upon dead

organic matter or in or upon some living host, just like the microbes. They grow in absence of light, and are essentially terrestrial, sometimes semi-aquatic, organisms. As a rule, fungi consist of two parts, the mycelium and the sporangium (fruit-bearing part). The mycelium is the vegetative portion of the plant. The sporangia are at the end of the hyphæ. The spores are smooth, spherical and from four to eight millimeters in diameter in mucoracemosus, a common representative of this class. Saprolegnia, achlya and the yeast fungus or saccharomyces might be mentioned here. Saprolegnia has in several places caused trouble with fishes by growing over their eyes and covering with their mycelium the entire head of the fish, which slowly succumbs to the parasite. Yeast fungi in a water supply might indicate contamination by kitchen refuse or by refuse from breweries and other establishments in which yeast is used.

With the fungi I will close the chapter of contamination with living (organic) vegetable organisms, and will consider briefly a few of the living animal organisms which have given more or less occasion for complaint when present in large numbers in a water supply.

The protozoa are the lowest organisms of the animal kingdom. They are minute organisms, consisting strictly of one cell, but frequently found in aggregations of many cells, each individual cell preserving its identity. The protozoan cell is a mass of protoplasm, possessing all the properties of the protoplasm of higher animal cells. It varies in size from a microscopic point to one inch in diameter. Its form may be regular or it may have a cell wall and a definite symmetrical outline. It contains usually a contractile vacuole, which has the faculty of contracting and expanding, and also of discharging gaseous and watery matter through the cell. The simplest protozoa absorb solid particles of food at any point on their surfaces. Digestion takes place within the cell.

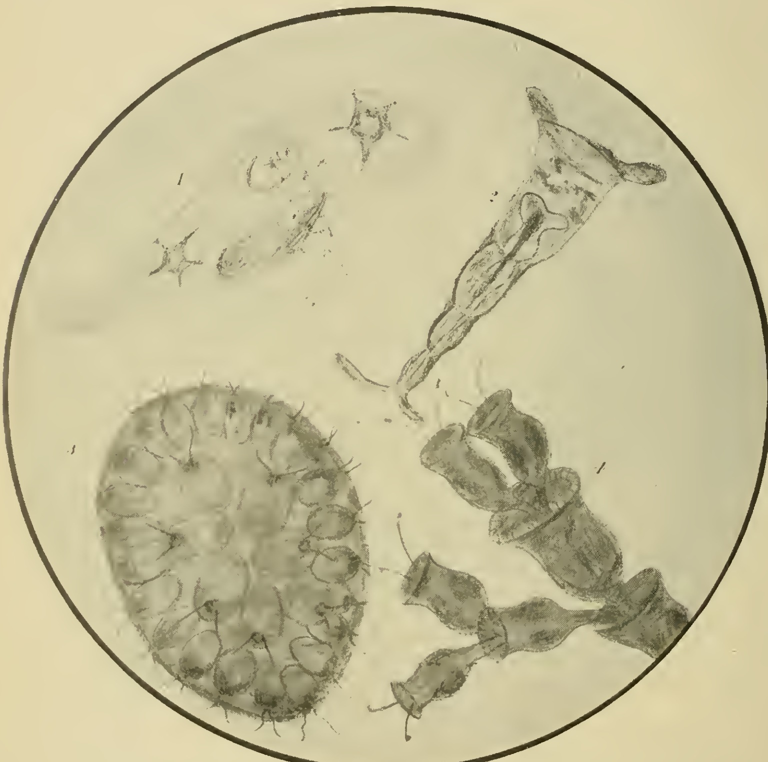
Higher protozoa have a distinct oral aperture through which the food enters, a sort of pharyngeal canal and an anal opening, through which undigested particles of food can pass. Multiplication takes place by binary division, by encystment and formation of spores, or by conjugation followed by increased power of division. The amœba is probably the simplest representative of the lower protozoa. It is formed of a soft, colorless, granular mass of protoplasm, possessing extensile and contractile power; has lobose finger-like processes, and ingests its food by flowing around and engulfing it. Frequently the ingested food material (diatoms, algæ, etc.) is plainly conspicuous. The amœba is generally found in shallow

ditches and ponds. Synura, cryptomanas and euglena are free-swimming protozoa (animalcules), found sometimes in water supplies in considerable numbers; also dinobryon, peridinium, glenodinium, paramæcium and uroglena, the latter having caused considerable annoyance in certain water supplies. The uroglena is described by G. T. Moore as follows: "Uroglena is found in New England, and has been reported as far west as Indiana. The probabilities are that it is widely distributed in this country, but has not

1, Synura (*Protozoa*); 2, Euglena (*Protozoa*); 3, Beggiatoa (*Schizomycetes*); 4, Amœba (*Protozoa*).

been recognized in many localities. In appearance uroglena resembles a colorless sphere, with numerous small greenish cells imbedded in its periphery. The whole colony measures sometimes almost one-half millimeter in diameter, although it is usually much smaller. The individual cells are each provided with a pair of cilia of unequal length, and it is by the vibration of these that the whole colony is revolved through the water. Each cell of the colony contains a nucleus, a red spot and a single greenish color body, besides

several vacuoles. In addition, there is a considerable number of oil globules, and it is the liberation of this oil which causes the fishy, oily taste and odor produced by uroglena. Among the algæ and schizophyceæ the contamination is nearly always brought about by decay, but in this case the trouble is produced simply through the mechanical breaking up of the organism and the consequent liberation of the oil contained within the cells. Usually the pumping or gravity necessary to distribute the water is sufficient to free



1, Paramæcium (*Protozoa*); 2, Rotifer (*Rotifera*); 3, Uroglena (*Protozoa*); 4, Dinobryon (*Protozoa*).

the oil, for the cells are very fragile. In one instance, where the water was used almost continuously for several days for washing caterpillars off the trees, a marked increase in the disagreeable odor and taste was the result. The exact nature of this oil is not very well understood. It is non-volatile at the temperature of boiling water, and seems to resemble the oils obtained from diatoms and cyanophyceæ. No sexual method of propagation has as yet been

observed in uroglena, but it has a rather peculiar method of cell division, which enables it to multiply rapidly. Before a cell divides it turns in the periphery of the hollow gelatinous sphere until it is in a position at right angles to the one usually occupied. Then, at the end of the cell which originally pointed toward the center of the sphere, there are formed a pair of cilia, like those at the opposite pole, and a red spot appears. The cell then begins to be sharply constricted, and, as it gradually divides, the two halves are drawn

Daphnia (*Crustacea*).

back through an angle of 45 degrees, so that, when the new cells are finally formed, they occupy a position similar to the one normally held by the mother cell. When a colony becomes too large, it breaks up into individual cells, and these soon, by repeated division, grow into new spheres. In addition to this mode of propagation, nesting spores are formed, which enable the organism to survive conditions which would otherwise exterminate it. In this

country uroglena seems to thrive best in cold temperatures, it usually occurring in greatest numbers when the water is frozen over. Just the reverse is true in Europe, where it is more abundant in July and August, and disappears entirely at the approach of cold weather."

Synura, also a protozoa, and probably few others have given rise to contamination of water sources by imparting bad odor or smell.

So far as I know, no case of water contamination is known in our state which could be attributed to one or the other mentioned protozoa. Occasionally, during microscopical examination of water, we meet with very interesting animalcules, among which are rotifera and crustacea.

The rotifera are quite highly organized multicellular animalcules, which have a well-defined digestive system, a set of jaws for mastication, salivary glands, an œsophagus, gastric glands, a stomach, intestines and an anus. Males, as well as females, are observed, the latter generally predominating.

They are bilaterally symmetrical, and have a corona of cilia springing from disk-like lobes surrounding the mouth at the anterior end. With these cilias they create currents in the water, whereby food particles are carried into the mouth. The rotifera have many different forms, from the simplest circle up to the most complex forms. Beside the rotifera a still more highly organized class of animalcules sometimes make their appearance in water supplies. These are the crustacea, which are about the size of a pin head. The body of the organism is segmented. In some cases there are distinct head and tail regions. They have one or two pairs of antennæ, springing near the head. The feet vary in number, position and character. There is one conspicuous eye, usually black or reddish, situated in the head region. Near the mouth are two mandibles, and near them the foot jaws, armed with spines or claws. There is a heart, that causes circulation of colorless blood, and well-marked muscular, digestive and reproductive nervous systems.

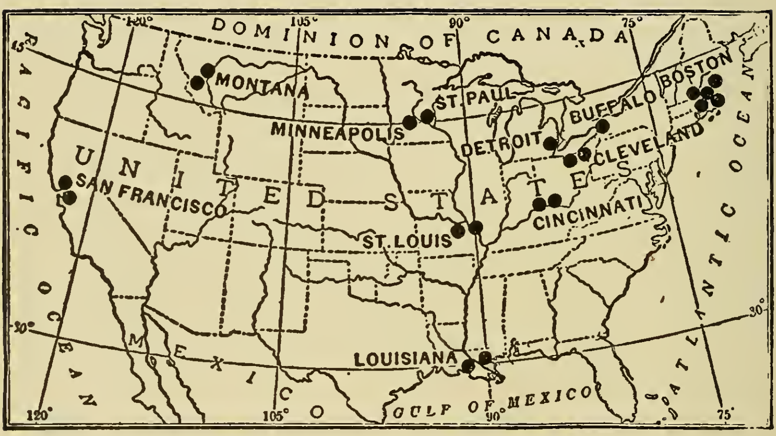
When present in very large quantities, these organisms may transmit a faint fishy odor to the water in which they live. Daphnia and cyclops are common representatives of this group of animalcules.

The last chapter on contamination of water with organic matter is that treating of dead organic substances.

Decaying leaves, plants, vegetable and animal matter of all kinds are very liable to gain access to a water supply, and especially

to those which derive their water from streams, lakes and sometimes wells. The presence of large amounts of vegetable and animal detritus is objectionable in any water supply, not only from an esthetic point of view, but also from the fact that it offers a most suitable medium for the growth of the greatest enemies of the human race—the disease germs which thrive and multiply luxuriantly in such an environment. Then it might be well to mention some common sources of contamination of wells with organic kitchen refuse. I have several times found in contaminated wells tissue of animal origin, starch cells, yeast and other fungi, beside bacteria of different kinds. In all these cases it was shown that defective location and construction made it possible for surface drainage to reach the water in the well. A tubful of water used in washing soiled clothing, for instance, from a typhoid fever patient, and carelessly thrown about the premises, may create the most virulent outbreak of the disease through the contamination of the water from a nearby well, into which some of the wash water, impregnated with the specific disease germ, had gained access. Numerous other examples of this kind could be given were it not for the limited time and space to which I must confine myself; but I hope the few examples given will have shown the great value of a technical, chemical and biological examination of a public water supply and its bearing upon the sanitary condition of a community. When we realize the necessity of the formation of a triple alliance between the engineer, the chemist and the biologist, we have it in our power to free the human race from most of the evils arising from an impure water supply.

Use has been made freely of Mason's work on Water Supply, Whipple's Microscopy of Drinking Water and other contributions dealing with the subject.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THE NEW WORKS AND WATER SUPPLY OF THE BUTTE WATER COMPANY.

BY CHARLES W. PAINE, MEMBER MONTANA SOCIETY OF ENGINEERS.

[Read before the Society, January 10, 1902.*]

THE City of Butte lies upon the northerly side of Silver Bow Creek, upon ground rising from an elevation above sea level of about 5400 at the Creek to 6250 at the Company's High Service reservoir. It is on the western slope of the Rocky Mountains about four miles west of the crest of the Continental Divide. Its water supply has at different times been derived from various sources; the rapid and surprising growth of the City necessitating constant changes and enlargement of the system. In 1891, when the works came under the present management, they were largely rebuilt and the capacity greatly increased. It was then believed that ample provision had been made for the needs of the City for many years. An increase in population of nearly two hundred per cent. in ten years had, however, not been contemplated, and before six years had passed the capacity of the new plant was taxed to its utmost to meet the demands upon it. It was then determined to put in the new works which it is the purpose of this paper to describe.

The new works consist of (1) a pipe line from the Big Hole River to the City, 27.2 miles in length; (2) three reservoirs, viz.: one high service reservoir near the upper part of the City, one reservoir (called the West Side reservoir) designed to supply the middle section of the City, and one reservoir on the South Fork

*Manuscript received October 6, 1902.—Secretary, Ass'n of Eng. Socs.

NOTE.—Plan of West Side reservoir and profiles of pipe lines, received too late for publication with Mr. Paine's paper, will be presented in the JOURNAL for November.

of Divide Creek, 18½ miles from the City, serving as a distributing reservoir; and (3) two pumping stations, viz.: one at the West Side reservoir for supplying the high service reservoir, and one at the Big Hole River.

THE PIPE LINE.

The pipe line, put in in 1891 to convey the water of the Basin Creek reservoir to the City, is made up largely of wooden stave pipe, built by the Excelsior Wooden Pipe Company, of San Francisco. This pipe has rendered such satisfactory service that it was decided, for this reason and because of economy in first cost, to use as much wooden pipe as possible in the new lines. Out of the entire line there are about 6.5 miles of steel pipe and 20.7 miles of wooden pipe. From the South Fork reservoir to the City, the wooden pipe is a banded redwood stave pipe, built continuously in the trench. It is 24 inches inside diameter and is designed to carry 8,000,000 gallons daily.

In computing the capacity, Kutter's formula was used, the value of n being taken as 0.010. The pipe was built under the well-known Allen patent. The staves were made from perfectly clear, well-seasoned California redwood, finished to a thickness of 1 7-16 inches. The edges of each stave were dressed accurately to radial planes and the sides were dressed to conform to the inside and outside circumferences of the pipe. The bands are of round steel, 7-16 inches in diameter, the two ends being connected by a malleable iron shoe. The specifications prescribe that the bands shall have a tensile strength of from 58,000 to 65,000 pounds per square inch, an elastic limit of 60 per cent. of the tensile strength, an elongation of 24 per cent. in 8 inches and a reduction of area of 50 per cent. Also that the steel shall admit of being bent cold 180° flat upon itself without signs of fracture. Before being placed upon the pipe, the bands were coated by dipping in a bath of hot asphaltum. The tongues, connecting the abutting ends of the staves, are of No. 12 steel 1½ inches in width and slightly longer than the width of the staves. The staves varied in length from 10 to 24 feet and were made to break joints not less than 24 inches.

As soon as the pipe was completed, it was covered with earth to a depth sufficient to protect it from the sun, and as soon as convenient the final covering was put on. This is nowhere less than 2 feet.

The spacing of the bands varies with every 5 feet change in pressure and is at the rate of 358 bands per 100 feet head per 100 lineal feet. The maximum distance between bands is 12 inches.

The variation in cost of wooden pipe corresponds quite closely with variation in head, and more care in making the location is therefore demanded than with steel pipe, which permits a much wider range of pressure without a change in price. The price per lineal foot of wooden pipe changes with every 10 feet change in head. With steel pipe, using the standard commercial gauges, the change occurs generally with every 50 feet change in head. In making the location over the rough, hilly country traversed by this line, it was found that the cheapest line was not one following the hydraulic grade line closely. It was usually cheaper to cross valleys and ravines boldly, even if this involved the introduction of steel pipe for the heavier pressures than to attempt to follow the grade line around them.

Starting at the Big Hole River, with elevation 5393 at low water, the line rises sharply up the mountain side to elevation 6178, 2 feet below the intake chamber at the South Fork reservoir. This elevation is reached at a point about 3000 feet from the river. A stand pipe, or overflow pipe, is here connected to the main pipe and extends up to the hydraulic grade line at elevation 6235. Seven hundred feet beyond this Charcoal Gulch is crossed. Here 630 feet of steel pipe are used. From Charcoal Gulch to the reservoir the line is at all points kept below the level of the intake chamber, to insure that the pipe shall always be full of water. It follows the eastern slope of Fleecer Mountain in a northerly direction to the South Fork reservoir. From the South Fork reservoir to the West Side reservoir the line was kept as near as was found economical to the hydraulic grade line. The Continental Divide is crossed at elevation 6075. There are four sections of steel pipe in this line, at points where the head was beyond the limit for wooden pipe. It was considered desirable to control the flow of water in the pipe at the West Side reservoir in Butte, also to maintain the wooden pipe full at all times in order to prevent decay of the wood. This involved the possibility of closing the line completely and throwing upon the entire line the pressure due to the elevation of the South Fork reservoir. Under such condition the greater part of the line would be subjected to pressures too great for wooden pipe, and a pipe line, strong enough to sustain the possible pressure would be required. To overcome this difficulty, automatic regulating valves were placed in the line, dividing it into five sections, in each of which the additional pressure, thrown upon the line at any point by shutting off the flow at the lower end, is that due to the difference in elevation between the hydraulic grade line at the given point and the elevation of the water at the upper end of the

section. The line of maximum pressure is made up of a series of level lines stepping down from the level of the South Fork reservoir to that of the water at the head of the last section. The regulating valves were set in concrete chambers arched over and covered with earth. The operation of the valves is as follows: On closing the valve at the West Side reservoir, water rises in the chamber at the head of the section next to the reservoir, lifting the float attached to the stem of the regulating valve and closing it. This is repeated in every section. The valves adjust themselves to any given flow in a similar manner. Should any valve fail to act, water flows over a waste weir, set slightly above the elevation necessary to close the valve and escapes through a drain pipe.

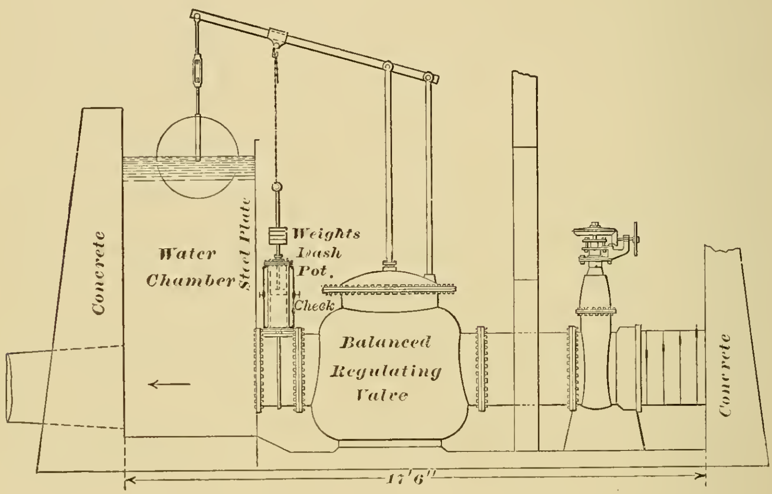


Fig. 1. Butte Water Works. Section of Regulating Chamber.

Some trouble was experienced at first from water hammer caused by the valves closing too quickly; this has been remedied by attaching dashpots to the levers operating the valves. The dashpots are cylinders with closely fitting pistons connected to the lever. The attachment is made adjustable by means of a chain so that the dashpot may be made to come into action at such time as experience may show to be best. The cylinders are completely filled with alcohol. The time required in closing the valve is regulated by a valve on a by-pass connecting the two ends of the dashpot. Another by-pass, with a check valve, permits much more rapid movement in opening.

The introduction of the valve chambers reduced the cost of the line approximately $90,000 below that of a continuous or unbroken

line. Data are not available for comparison with the more probable alternative line, one with a reservoir on the south side of Silver Bow Creek.

On the line from the South Fork to the West Side reservoir there are ten gate valves in addition to the regulating valves. There are also drains or blow-offs at low points, and air valves at all summits. For admitting air when the pipe is being drained, ordinary vertical 2-inch brass checks are used. On the Big Hole

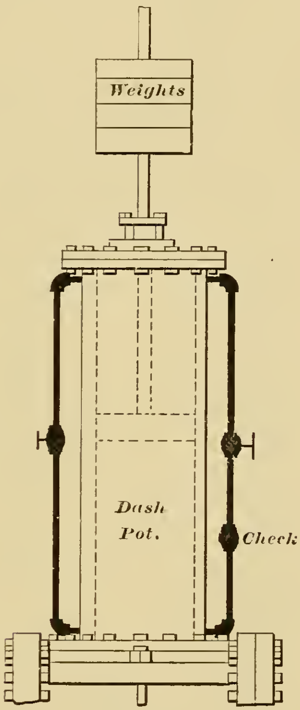


FIG. 2. DASHPOT DETAILS.

line there is but one gate valve outside the pumping station. This is at the South Fork reservoir and is designed to be used only in connection with the by-pass between the two lines. When closed, it brings no additional pressure on the line, an overflow being provided near the valve.

Eight-inch blow-offs are set in low points, and air valves and check valves at summits. The wooden pipe on this line is 26 inches in diameter. It was found that because of less friction, and the consequent reduction of pressure, 26-inch pipe was cheaper than 24-inch.

STEEL PIPE.

The specifications for steel pipe call for medium open-hearth steel having an ultimate tensile strength of not less than 60,000 nor more than 68,000 pounds per square inch, an elastic limit of not less than one-half the ultimate strength, an elongation of 22 per cent. in 8 inches and a reduction of area at fracture of 40 per cent., and capable of being bent cold 180 degrees to a diameter equal to the thickness of the piece tested. Rivets were required to be of the best soft-rivet steel, capable of meeting the Manufacturers Standard Specifications.

The pipe was built with cylinder joints, each alternate section telescoping into slightly larger adjacent sections. Longitudinal joints are double riveted, roundabout seams single riveted. The shop riveting was done by hydraulic riveting machines, the field work by pneumatic riveters, the Boyer Long Stroke machine being used. After being riveted and calked in the shop, every pipe was tested to a pressure equal to 1.8 times the working pressure, and made perfectly tight under this pressure before being coated. The coating used was Assyrian and Alcatraz asphalt, at 300 degrees temperature.

The pipes were usually shipped in lengths of 28 to 30 feet.

The small angles were made by bands. In most cases the pipe was laid to the required angle, the adjacent pipes separated by only a few inches; bands were then fitted to make the connection. The large angles were made in the shop.

Plates having a thickness of 7-16 inch or more were drilled instead of being punched. Manholes were placed on the steel-pipe line at intervals of about 500 feet.

TRENCHING.

The trenches were made 4 feet wide on the bottom, with slopes generally ½ to 1, and a depth sufficient to give 2 feet cover. This required the removal of 90,334 cubic yards of earth, 71,336 cubic yards loose rock and 21,416 cubic yards of solid rock.

RESERVOIRS.

The South Fork reservoir is located on the South Fork of Divide Creek, 18½ miles from the City, at an elevation of 6176 above sea level. It has a capacity of 13,471,000 gallons. It is supplied by the flow of the creek and pumping from the Big Hole River.

The reservoir is formed by a dam 35 feet high and 330 feet long. The area to be covered by the dam and reservoir was stripped

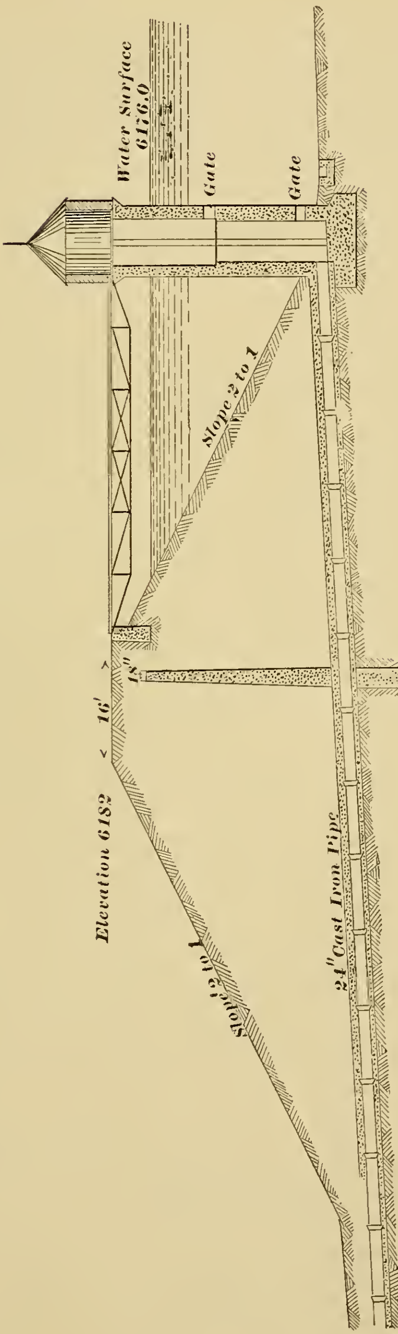


FIG. 3. SOUTH FORK RESERVOIR. SECTION OF DAM.

to the gravel, and on the site of the dam a core pit was excavated to a depth of 30 feet below the original bed of the stream and well into the bed rock. In this pit a concrete core wall was built. This is 3 feet wide from the bottom up to the level of the original surface, and battering to 18 inches at the top, which is 1 foot above high water in the reservoir. Concrete was mixed by hand in the proportions of 1 barrel Portland cement to 14 cubic feet of sand and 28 cubic feet of broken stone. The up-stream side of the wall was plastered with cement mortar mixed 2 to 1. The dam is 16 feet wide on the top, with slopes of 2 to 1 on each side. The top is 6 feet above the water line. Very little good material could be found in the vicinity of the dam. The best obtainable was a mixture of sand and gravel with a good many stones ranging in size from coarse gravel to several cubic feet. This was found in the bottom of the reservoir below the muck. It was of a somewhat clayey nature, and by throwing out the large stones a fairly good material was secured. The quantity was only sufficient to put on the water face about 3 feet in thickness. The remainder of the embankment is composed of disintegrated granite. All material was wet, and rolled with a heavy grooved roller or rammed by hand. The water face was paved with irregular-shaped granite boulders 12 inches in thickness. A concrete gate and screen chamber is located at the foot of the slope on the water side. It has two openings at different elevations, controlled by sluice gates. A 24-inch cast iron outlet pipe and an 8-inch drain pipe are laid from the gate chamber through the dam. They are encased in concrete which rests on the undisturbed earth. A steel bridge, 60 feet long, connects the gate chamber with the top of the dam. An overflow or waste weir 20 feet wide and 6 feet deep is provided at the north end of the dam. There is also a diverting ditch having a capacity of about three times the greatest observed flow of the stream, with gates so arranged that the stream may be diverted and carried around the reservoir. During construction the stream was carried around the reservoir in this ditch.

Several small springs were found in excavating for the core pit. A weir was put in and the flow measured before filling the reservoir. No increase has been observed since.

The quantities on this work are as follows:

43,658 cubic yards earthwork.

3143 cubic yards loose rock excavation.

3166 cubic yards solid rock excavation.

1478 cubic yards concrete.

WEST SIDE RESERVOIR.

The West Side reservoir is located near the head of Excelsior street in Butte. In shape it is irregular, about 180 feet in average width by 800 feet in length. The ground slopes to the South from 6 to 10 feet to 100. The northerly side of the reservoir follows approximately the contour of the hillside at elevation 5962. At each end and on the south side a concrete wall and earth embankment are built. The shape was determined somewhat by the character of the material. As far as practicable solid rock excavation was avoided.

From contour 5962 on the north side the ground was excavated to a slope of 2 to 1 down to the bottom plane. The material excavated was placed against the outside of the wall, forming an embankment 25 feet wide on top, with a slope of 1.5 to 1. The excess, above what was required for this, was deposited in waste banks. The concrete wall is 2½ feet thick on top, and has a batter of 2½ inches per foot on the water side and 1 inch per foot on the outside face. The maximum depth of water is 19 feet. The bottom and sloping portions of the sides are lined with concrete 12 inches thick on the bottom and 6 inches at the top of the slope. The concrete was mixed, in proportions of 1 barrel cement to 14 cubic feet of sand and 28 cubic feet of broken slag, by a Cockburn machine mixer, and run to the work in cars. That for the walls was dumped into place directly from a track laid on top of the forms. 0.83 of one barrel of cement made 1 cubic yard of concrete in place. Two expansion joints were made in the wall. They are vertical transverse joints, with soaped faces to prevent adhesion and a cut-off wall of clay to prevent the passage of water. The bottom lining was divided into 20 feet squares by strips of boards tapering from ¾ inch to ½ inch in thickness for convenience in removing. After the cement had become dry the boards were removed and the joints filled with a mixture of Alcatraz asphalt and lime dust run in hot.

The top of the wall has a coping of sandstone 6 inches thick and 30 inches wide. A 6-inch curbing of concrete is set at the top of the slope on the north side.

The inlet chamber is on the west end of the reservoir. Water is discharged over a weir. A 24-inch gate valve and a 24-inch regulating valve are set in the chamber, the arrangement being like that of the regulating chambers on the pipe line, except that the float operating the valve is placed in a tank connected by a pipe with the reservoir and does not act until the reservoir is full. It then closes the valve completely. As soon as the water in the reservoir

drops below elevation 5960, and ceases to supply the tank, water in the latter drains out and the valve is again opened. There are two 14-inch outlets and an overflow at the east end. A 14-inch pipe is laid along the foot of slope of the embarkment, connecting the 24-inch main with the outlet pipes. Another connection, by a 10-inch pipe, is made with the City system at a lower elevation under about 350 feet head.

The construction of this reservoir required the excavation of:

4607 cubic yards of solid rock.

1528 cubic yards of loose rock.

36,290 cubic yards of earth.

In the lining and walls there are 9080 cubic yards of concrete. The cement used was of the Lehigh brand.

HIGH SERVICE RESERVOIR.

A reservoir of the same general construction as the West Side reservoir was built in Walkerville to supply the districts lying above the level of the latter. It has a capacity of 3,255,000 gallons. The water surface is at elevation 6253.

THE BIG HOLE PUMPING STATION.

The Big Hole pumping station is located about 2½ miles from Divide station, on the Oregon Short Line Railway. The building is of brick, 85 feet by 102 feet. Four Sterling water-tube boilers, of 300 horse power each, have been installed. Also one duplex triple-expansion pumping engine manufactured by the Jeanesville Iron Works Company, of Jeanesville, Pa., having a capacity of 1,500,000 gallons in 24 hours, and a guaranteed duty of 75,000,000.

A high-duty pumping engine is now being erected. This engine is of the Horizontal direct-acting crank and flywheel type, the steam end of which is a Nordberg triple-expansion Corliss engine, with cranks coupled at 120 degrees to a common shaft. The pumps are located back of and in line with the steam cylinders. The plungers are connected to and driven by the extended steam piston rods. The diameters of the steam cylinders are 24, 44 and 62 inches. The diameter of the water plungers is 9 inches and the stroke is 52 inches.

The pumps are double-acting and of the outside-packed-plunger type. The air pump, boiler feed pump and jacket drain pump are operated by means of a rock shaft and levers attached to the connecting rod of the low pressure engine. The engine has a guaranteed duty of 135,000,000 foot pounds per 1,000,000 British

thermal units, when running 300 feet per minute with 150 pounds initial steam pressure, 3 pounds absolute back pressure and pumping 4,000,000 gallons per 24 hours, against a hydraulic head of 840 feet.

The boilers are connected to a self-supporting steel stack 8 feet 9 inches in diameter and 151 feet high. Water is taken from wells and tunnels beside the river, and from the river when necessary.

HIGH SERVICE PUMPING STATION.

A new brick pumping station, 38 feet by 72 feet, has been built at the West Side reservoir and two Worthington pumps and two boilers installed. The machinery and boilers were taken from pumping stations in the city, now abandoned. The plant supplies the High Service reservoir through a 12-inch main.

In conclusion .two features of special interest may be again mentioned: First, the great head against which the pumps work at the Big Hole station.

From low water in the river to the level of the inlet chamber at the South Fork reservoir, the lift is 787 feet. The addition of the friction head, for the full capacity of the line, gives 840 feet as the total dynamic head. This pressure, while not unusual for mining or oil-line pumps, is greater than can be found in any water works plant of equal capacity, with which the writer is acquainted.

The second interesting feature is the fact that the water is taken from a stream flowing into the Gulf of Mexico, carried across the crest of the continent and delivered on the banks of a tributary to the Pacific.

The work above described has been in charge of the writer as constructing engineer, under the direction of Mr. Eugene Carroll, chief engineer. The pipe line has been largely under the immediate supervision of Mr. C. D. Vail, principal assistant. The trenching and reservoir work was done by Winters, Parsons & Boomer, contractors, of Butte. The steel pipe was manufactured and laid by the Wolff & Zwicker Iron Works, of Portland, Ore. The wooden pipe was built by the Excelsior Wooden Pipe Company, of San Francisco, Cal.

AN HAWAIIAN SUGAR PLANTATION.

By Charles W. Goodale, Member Montana Society of Engineers.

[Read before the Society, January 10, 1902.*]

A visit to the Hawaiian Islands in the summer of 1901 gave me an opportunity to see extensive irrigating operations in the cultivation of sugar cane, and the following notes may be of interest to the members of the Society.

It may be a surprise to many that irrigation is necessary at all in these tropical islands, and in certain districts the precipitation of moisture is certainly abundant enough. At Hilo, for instance, the principal town on the largest island of the group, Hawaii, it has been said that "rain falls forty days in the month"; but, while irrigation is not required in this and other districts on the windward side of the islands, the western or leeward slopes frequently suffer from drought.

The development of these leeward lands had received very little attention before the annexation of the group to the United States, for the reason that capital was not inclined to invest in the pumps and other machinery necessary for irrigating while there was any danger of a duty being placed on Hawaiian sugar; but, after annexation, large tracts of undeveloped land were secured by plantation companies, either under long-term leases or by purchase, and enterprises requiring the outlay of considerable capital were inaugurated.

On the western side of the island of Oahu, and distant from Honolulu about 50 miles on the Oahu Railway, is the plantation of the Waialua Agricultural Company, and this will be described in some detail.

The amount of land included in the property is about 10,000 acres, extending from very near tide water to a height of 600 feet above the sea. It has been found that the cane crop, under conditions existing at the islands, takes about 10,000 gallons of water per acre, and this plantation must, therefore, make sure of a supply of about 100,000,000 gallons per day. The available streams furnish only about 30,000,000 gallons per day during the summer, and it is, therefore, necessary to provide 70,000,000 gallons from other sources. As the land is built up of successive lava flows, inclining slightly toward the sea, and as these flows vary in character from hard, compact lava to what might be called cinder beds, artesian wells near the sea have given copious supplies of water, and nearly

*Manuscript received October 6, 1902.—Secretary, Ass'n of Eng. Socs.

all the amount mentioned above (70,000,000 gallons per day) is obtained from about fifty 12-inch wells. It should be explained that the mountain slopes are very much broken by deep ravines and, therefore, the rain-fall, which is abundant in the high mountains, readily finds its way into the porous or open strata; and these, when tapped by wells, give the needed water supply.

The plantation has six pumping stations, equipped as follows:

Station No. 1.—Duplex double Riedler pump, made by Fraser & Chalmers; maximum capacity, 4370 gallons per minute, or over 6,000,000 gallons per 24 hours, to a height of 156 feet. The water for this station is taken from three 12-inch wells 320 feet deep, and the discharge is pumped through 3720 feet of 20-inch pipe. Babcock & Wilcox boilers.

Station No. 2.—Duplex double Riedler pump, Fraser & Chalmers; maximum capacity, 6944 gallons per minute, or nearly 10,000,000 gallons per 24 hours, to height of 250 feet. The water for this station is taken from seven wells 320 feet deep; 4100 feet of 30-inch discharge pipe. Babcock & Wilcox boilers.

Station No. 3.—Two triplex double Riedler pumps, Fraser & Chalmers; maximum capacity, 7500 and 6160 gallons per minute, or 10,800,000 and 8,870,000 gallons per 24 hours, to a height of 340 and 550 feet. The water for this station is taken from eleven wells, averaging 357 feet deep, with 4200 feet of 28-inch pipe and 8700 feet of 26-inch pipe to carry the discharge of these two pumps to the proper elevation. The boilers are of the Sederholm type, 300 horse power each and a Greene Economizer is installed in connection with the boilers.

In order to place the pumps at an elevation that would make it easier for them to draw water from the wells, an excavation 47 feet deep, 75 feet wide and 78½ feet long was made, representing a removal of 12,000 cubic yards; and the walls, made of lava rock, required 6000 cubic yards of masonry, including the foundations of the pumps.

The equipment is thoroughly up to date in all particulars, the plant having been designed by Mr. H. A. Allen, of Fraser & Chalmers.

This station is located in a deep ravine. The object in selecting this site was to save in length of pipe line required to reach the desired elevation and, of course, to have as little friction as possible. By going down nearly three-quarters of a mile nearer the sea, a depth of 20 feet in excavation could have been saved, but the length of the pipe lines would have been increased by 3200 feet. From the bottom of the excavation, tunnels run out into the sur-

rounding rock, and the wells are reached by pipe lines through these tunnels.

The cost of well boring averaged $6 per foot on contract, and the tunnels were paid for at the rate of $2.75 per cubic yard, the contractors removing and hoisting out their own excavated material. The rock did not, however, require blasting.

Station No. 4.—Two Duplex double Riedler pumps; one of a capacity of 6944 gallons per minute, or nearly 10,000,000 gallons per 24 hours, to a height of 370 feet; the other throwing 3850 gallons per minute, or nearly 5,500,000 gallons per 24 hours to a height of 220 feet; also one triplex double Riedler pump, of a capacity of 5600 gallons per minute, or about 8,000,000 gallons per 24 hours, to a height of 550 feet.

The water for this station is taken from a pond which is supplied by springs, and from flowing artesian wells, fourteen in number. The water rises in these wells to 4 feet above sea level, the station being located about one-half mile from the beach. One well is only 16 feet deep, while the others range from 40 to 52 feet in depth, except in one case where a well was drilled to a depth of 420 feet. This was driven for prospecting purposes, to see whether great depths would give additional flow. For the first 47 feet, it was through hard rock; it then struck cinder or softer rock. At 87 feet a flow of salt water was encountered. By casing up the well down through this layer of rock carrying salt water and allowing the casing to project above the top of the well, the salt water was prevented from mixing with the fresh.

It should be stated that the wells that furnish this supply are all somewhat brackish, but not sufficiently impure to injure the water for irrigating purposes.

This station has 6260 feet of 30-inch discharge pipe, 2280 feet of 20-inch discharge pipe and 9200 feet of pipe 26 inches in diameter. Babcock & Wilcox Boilers.

Station No. 5.—Two duplex cross-compound pumps, made by the Risdon Iron Works, having a capacity of 2080 and 2777 gallons per minute, or 3,000,000 and 4,000,000 per 24 hours, to a height of 70 and 75 feet.

The water comes from seven 12-inch artesian wells and one 8-inch well, the depth being from 470 to 570 feet. There are two discharge pipe lines of 2140 feet each; one 16 inches in diameter, the other 20 inches in diameter. Babcock & Wilcox Boilers.

Pumping Plant at Mill.—One duplex double Riedler pump, Fraser & Chalmers, of a capacity of 3480 gallons per minute, or 5,000,000 gallons per 24 hours, to a height of 110 feet.

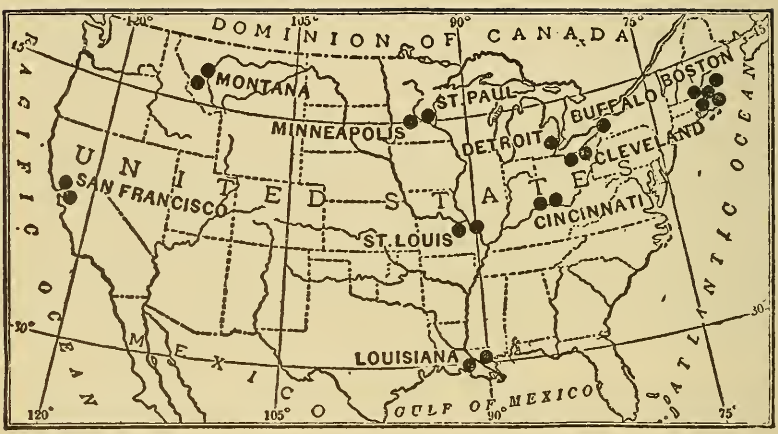
These several pumping plants, all being covered with steel buildings, represent, completed, an expenditure of over $1,250,000.

The equipment of the plantation also includes a sugar mill, capable of handling 1200 tons of sugar cane per day, the cost of which was about $600,000. The mill building, which is of steel construction, includes one room 240 feet x 90 feet and another one 180 feet x 90 feet. The power is obtained from a 30-inch x 60-inch Hamilton-Corliss engine, the exhaust from which is used in boiling the juice.

In order to handle the cane economically quite an extensive railroad system is required. This includes 32 miles of permanent track, gauge 36 inches, 25 miles of which have 35-pound rail, and the balance 25 pounds, and 8 miles of portable track, 20-pound rail. In the rolling stock are three Baldwin locomotives, Class 8, weighing 42,000 pounds each; also two others of smaller size; also 550 four-wheel cane cars, weighing 2600 pounds light and having a capacity of 5 tons.

The plowing is done by steam, two road wagons being employed, one at each side of the field, to drag the plow across. The steam-plow equipment includes five pairs of road engines with reels, and the cost of this machinery was about $100,000.

The coal supply is obtained from Australia and from the Roslyn mines in Washington, and costs from $6 to $7 per ton in Honolulu, or nearly $9 delivered at the steam plants.



DOMINION OF CANADA
MONTANA
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MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
PACIFIC OCEAN
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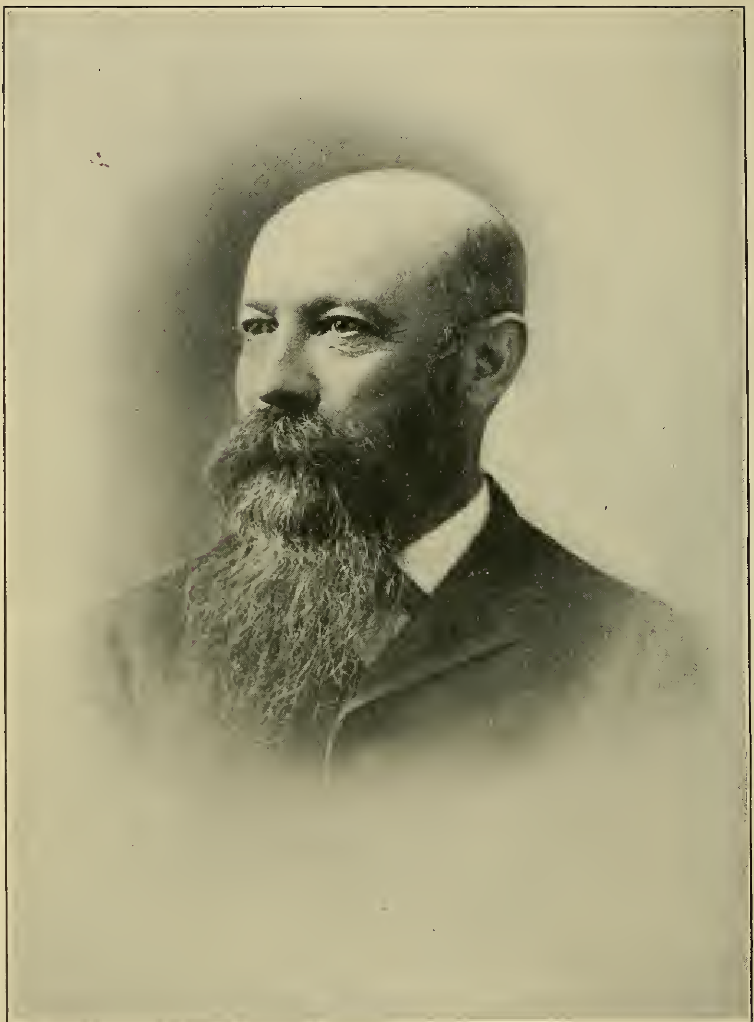

JAMES SPIERS.

Member Technical Society of the Pacific Coast.

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THE ABOLITION OF GRADE CROSSINGS IN MASSACHUSETTS.

BY EDMUND K. TURNER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, October 22, 1902.*]

IN the early days of railroad construction in this country but little attention was paid to the avoidance of crossings at grade of railroads with public highways. Both railroad and public way followed the natural surface of the ground as closely as possible, in order to avoid expensive works of construction.

The territory through which the railroads were built, unlike that in the older and more thickly populated countries, was in most instances sparsely settled, and, as far as could then be seen, the question of crossing at grade was of little importance. At that time, also, the amount of money applicable to the construction and equipment of the new means of transportation was very limited. It was difficult to raise money for the absolute needs of construction, without considering any features that would add to the cost and could be dispensed with for the time being. To have provided for the avoidance of grade crossings would in many, perhaps most, instances have prevented or postponed for a long time the construction of the railroads. This question was therefore passed over for the time.

Little was known or could then be foreseen of the amount of business or number of trains to be expected on the railroads. The building and operation of railroads was a new business. No experience or precedents existed from which definite ideas as to the probable results could be formed, and there was but little to indicate the proportions to which the business of the country would grow within a comparatively short time, and of the increased require-

*Manuscript received November 20, 1902.—Secretary, Ass'n of Eng. Socs.

ments relative to the transportation and movements of both persons and property which such growth would bring about. One of the most important elements in causing this growth of business being the improved methods of transportation then introduced by the construction and operation of railroads.

During the first few years after the introduction of railroads the conditions remained without much change. There were few trains on the railroads and but little travel upon the public ways; consequently, but few accidents at grade crossings and but little to call attention to them. Possibly people using the public ways were more careful and had not become used to taking chances in crossing the railroad tracks. All movements were made in a more deliberate way. The trains were light and were run at a low speed; consequently, were more easily kept under control.

In 1835, when the first railroads carrying passengers in Massachusetts were finished and opened for travel, the population of the State was 670,000. In 1895 the population had increased to 2,500,000. The transportation needs, per inhabitant, had also increased in a proportion even greater.

With the increase in population and in the necessity for larger transportation facilities the danger at grade crossings became greater. More people used the public ways. The trains became more frequent, faster and heavier. In consequence of these changes the number of accidents at grade crossings increased, and the question of preventing the construction of more grade crossings and of protecting or abolishing those already existing became of sufficient importance to attract public attention. At first the protection by flagmen or gates of those persons moving along the public ways seemed sufficient, and for a time answered the purpose, but, with the great increase in travel, accidents at protected crossings became frequent, the danger to persons traveling on both highway and railway became greater, and the question of the abolition of grade crossings took shape.

In 1869 the Massachusetts Legislature passed an Act providing for the appointment of a railroad commission, to consist of three members, to be appointed by the Governor and to hold office for a term of three years. This commission has exerted a very powerful influence in all movements toward safer and better methods of construction and operation of railroads. At an early period in the existence of the board it took up the subject of grade crossings and made recommendations for the passage of laws on that subject, which have been strong factors in bringing the grade-crossing question to its present condition.

The mileage of railroads in Massachusetts in proportion to the area of the State was, at the time the commission was established, quite large as compared with other States, or even with more thickly populated countries, as shown by the following table:

TABLE I.

MILES OF RAILROAD TO SQUARE MILES OF TERRITORY IN 1869.

Massachusetts, 1 mile to	5.47	square miles.
New York, 1 mile to	14.12	" "
United States, 1 mile to	46.73	" "
Great Britain, 1 mile to	8.60	" "

In dealing with nearly all of the measures brought forward for the safety and convenience of the public, the railroad companies also have given their help. In very few instances have they offered serious obstruction.

In the first report of the Railroad Commission, the following statement regarding grade crossings appears:

"The control of this matter rests with the County Commissioners, but the Board will take the liberty to suggest that in future crossings at grade should not be allowed when it is possible to avoid them, and all roads should be carried over or under the railroad where it can be done. Some of the existing crossings might now be changed to bridges at no very great expense, and the Commissioners suggest to railroad companies the propriety of such changes on all the principal lines."

For several years the Railroad Commissioners called attention in their reports to the increasing number of accidents at grade crossings, and urged the Legislature to take action to prevent increase in the number of such crossings and to enter upon some policy for the gradual elimination of those already existing.

In 1882 the Legislature included in the statutes the General Railroad Laws (Public Statutes, Chapter 112), which embraced in its provisions one forbidding the making of new ways across at the same grade with existing railroads, or the laying out of railroads at the same grade across existing public ways, without first obtaining the consent in writing of the Railroad Commissioners, and, in most cases, that of the County Commissioners also. Since that date comparatively few new crossings at grade have been made, it being necessary to prove beyond question that such a course was absolutely necessary before the consent of the Boards could be obtained.

The prevention of new crossings having been thus provided for, the movement for the abolition of grade crossings already ex-

isting was continued, various measures having this object in view being introduced into the Legislature.

Meanwhile, many of the railroads were doing something toward the abolition of their crossings. As an example, the Fitchburg Railroad and its leased lines, with which the writer was at that time connected, between 1875 and 1890, got rid of twenty-five grade crossings. Some of these changes were made by alterations of grade, carrying public ways over or under the railroads; some by combining two or more crossings into one by building connecting pieces of public ways and a few by discontinuing ways which had become useless.

The above noted changes were made by agreement with the city or town authorities and with the approval in all cases of the Commissioners of the County in which the crossings were situated. The County Commissioners in all of these cases gave great assistance in arranging the preliminary agreements and in carrying out the work. The cost of making these alterations was in some cases borne entirely by the railroad company; in some a division of expense between the city or town and the company was agreed upon, but in none of these cases did the State contribute anything toward the cost.

The total number of grade crossings in Massachusetts, as shown in the reports of the Railroad Commission for each year from 1873 to 1901, also the number protected by gates or flagmen, the number not so protected, the miles of railroad and the ratio of crossings to miles of railroad, is shown in the following table:

TABLE II.

Year.	Number of Crossings.	Protected.	Unprotected.	Miles.	Number per Mile.
1873	2,228	376	1,842	1,657.9	1.34
1874	2,436	446	1,990	1,734.9	1.40
1875	2,660	526	2,134	1,782.5	1.50
1876	2,774	607	2,167	1,816.7	1.52
1877	2,776	569	2,207	1,837.4	1.51
1878	2,245	460	1,785	1,850.0	1.21
1879	2,151	491	1,660	1,861.8	1.16
1880	2,137	533	1,604	1,893.1	1.12
1881	2,155	567	1,588	1,927.9	1.11
1882	2,151	615	1,536	1,949.5	1.10
1883	2,143	651	1,492	1,953.5	1.10
1884	2,128	677	1,451	1,973.7	1.08
1885	2,118	706	1,412	1,981.7	1.07
1886	2,138	738	1,400	1,989.5	1.07
1887	2,128	765	1,363	2,018.3	1.05
1888	2,239	855	1,374	2,063.9	1.08

Year.	Number of Crossings.	Protected.	Unprotected.	Miles.	Number per Mile.
1889	2,218	922	1,296	2,066.8	1.07
1890	2,234	956	1,278	2,088.9	1.07
1891	2,219	978	1,241	2,086.9	1.06
1892	2,216	993	1,223	2,094.9	1.06
1893	2,178	968	1,210	2,119.5	1.03
1894	2,173	1,085	1,088	2,118.1	1.02
1895	2,192	1,112	1,080	2,114.4	1.03
1897	2,155	1,154	1,001	2,113.3	1.02
1898	2,103	1,147	958	2,101.9	1.00
1899	2,070	1,136	934	2,107.6	.98
1900	2,052	1,136	916	2,108.5	.97
1901	2,022	1,135	887	2,108.9	.96
1902	2,001	1,139	862	2,107.5	.95

The years given are as noted in the reports of the Railroad Commission. The notation was changed in 1897, leaving 1896 with no report.

From the above table it will be seen that during the earlier years noted there was a rapid increase in the number of grade crossings, due to the increase in mileage of railroads then taking place, and to the fact that at that time less restraint was exercised to prevent the establishment of such crossings on the new railroads then being built than has been the case in more recent years.

It will also be noted that the number of crossings in proportion to the miles of railroad is very large, being over one crossing to each mile of railroad, showing that the mileage of public ways in the Commonwealth is liberal.

Inspection of this table also shows some interesting features regarding the growth of the railroad systems of the State. Up to 1890 there was a constant and considerable increase in the total mileage. Since that date the gain in any year, as well as the total gain, has been small. The five years 1893-1898 show a small loss each year. The greater part of this loss is accounted for by the fact that some short railroads were discontinued and the tracks taken up.

It is also to be noted that the number of grade crossings increased very fast during the early part of the period covered, with quite a diminution between 1877 and 1885.

It is probable that, in the earlier years noted, the entire number of crossings on the railroads reporting was given, while during later years only those in Massachusetts were so reported. Private crossings also were in some cases included in the report, which, upon more careful examination, were afterwards excluded.

The table also shows that a very considerable increase in the proportion of crossings protected by gates or flagmen, or both, has taken place.

The proportion of crossings which are guarded to the whole number of existing crossings, at five-year intervals, is shown in the following table:

TABLE III.

1875	20 per cent.
1880	25 " "
1885	33 " "
1890	42 " "
1895	50 " "
1899	54 " "
1902	56 " "

But statistics show that the protection furnished does not prevent an increase in the number of accidents at crossings, as is shown by the following figures:

TABLE IV.

Year.	Casualties.	Killed.	Injured.
1874	7	5	2
1884	38	..	..
1894	65	19	46
1900	56	24	32
1902	44	25	19

The character of protection furnished does not prevent persons so disposed from passing onto the track in front of trains. It may, and generally does, provide warning, which, if reasonably heeded, would prevent accident, but the impatience of many, when restraint is offered to their movement in any way that their impulse suggests, prevents them from taking advantage of the safeguards which are provided.

There is also another source of danger from grade crossings, especially those not protected. Such crossings invite travel along the tracks from one crossing to another, which results in many accidents to persons. It has been found difficult, or, it might almost be said, impossible, by the railroad companies to prevent such travel, although clearly an act of trespass. The abolition of grade crossings and proper fencing of the approaches to ways under or over the tracks stops to a considerable degree such unauthorized travel along the railroad tracks.

In 1885 an Act was passed (Chapter 194), entitled "An Act to Promote the Abolition of Grade Crossings by Railroads and Highways," among its provisions the following:

"County Commissioners may act on receipt of petition from not less than twenty legal voters of the County wherein the crossing

is situated. Thirty days' notice of hearing to be given. The cost in the opinion of the County Commissioners not to exceed three thousand dollars. Not to be carried out if a special commission appointed by the Superior Court believes that the cost will exceed six thousand dollars, in which case the special commission annuls the action of the County Commissioners."

The next decisive step toward the abolition of grade crossings was taken in 1888. In that year the Legislature, by Chapter 99, resolved:

"That the Governor, with the advice and consent of the Council, be authorized to appoint three competent and experienced civil engineers, who shall investigate and report in print to the next General Court, on or before the first day of February, eighteen hundred and eighty-nine, upon the subject of the gradual abolition of the crossing of highways by railroads at grade, with such suggestions and recommendations as to the best methods of accomplishing such abolition as shall seem to them expedient. Such engineers shall include in their report recommendations as to the methods of apportioning costs and the payment of damages occasioned when such crossings are abolished. Said engineers shall have power to employ such clerical and other assistance as may be necessary for carrying out the objects of this resolve, and the engineers shall receive such compensation for their services as the Governor and Council may determine: provided, however, that the whole amount expended under the provisions of this resolve shall not exceed ten thousand dollars, and the terms of office of said engineers shall not extend beyond the first day of February, eighteen hundred and eighty-nine."

In accordance with the terms of the resolve, three engineers were appointed on the 11th of the next July—Augustus W. Locke, William O. Webber and George A. Kimball.

Personal examination of every grade crossing in the State was made by one or more members of the Board, and information regarding crossings was obtained from the railroad companies and from the cities and towns.

From the report of the engineers it appears that there were then in the State 2267 highways crossing railroads at grade, 1475 of them unprotected, 792 protected; 470 public ways crossing overhead railways and 278 crossing underneath,—a slight discrepancy between these and the figures in Table II from the Railroad Commissioners' report, probably due to a more careful count for the special commission.

Nearly all of these grade crossings were established when the railroads were built. The crossings per mile on the various railroads were as follows:

TABLE V.

Boston and Lowell, 1835	1 to 3.70 miles.
Boston and Albany, 1835	1 " 1.16 "
Fitchburg, 1848	1 " .79 "
Old Colony	1 " .99 "
New York and New England	1 " 1.66 "
Boston and Maine	1 " .80 "
Eastern	1 " .68 "
Boston and Providence	1 " 1.19 "
Central Massachusetts	1 " 1.09 "

Between January 1, 1879, and January 1, 1889, grade crossings in Massachusetts were abolished as follows:

TABLE VI.

Boston and Albany	15
Central Vermont	2
Connecticut River	5
New York and New England	1
Old Colony	21
New York, New Haven and Hartford	3
Fitchburg	23
Providence and Worcester	5

The Board of Engineers collected much valuable information as to the cost of abolition of crossings already accomplished, and made estimates of the probable cost of abolishing all of the crossings at that time existing in the State.

The Board divided the crossings into seven classes, according to the estimated cost, as follows:

TABLE VII.

Class.	Number.	Cost.	Total.
1	1,068	$7,000	$7,476,000
2	713	12,000	8,556,000
3	243	18,000	4,374,000
4	34	50,000	1,700,000
5	164	90,000	14,760,000
6	22	150,000	3,300,000
7	3	200,000	600,000
Grand total			$40,766,000

There were found crossings, about twenty in number, where the expense of abolishing them would be out of reasonable proportion to the benefits received; therefore, no estimate of the cost was made for these.

The Railroad Commissioners, in their 1884 report, estimated the total cost of abolishing all grade crossings in cities and in the populous parts of towns at one hundred millions of dollars,

which, from the experience of the past ten years, seems nearer the probable actual cost than the estimate of the Board of Engineers.

Some interesting computations were made by the Board of Engineers as to the value of time lost at various crossings by the detention of persons and teams.

One in Lynn, loss per day, $35.

One in Charlestown, loss per day, $50.

One in Roxbury, loss per day, $12.

These figures, while interesting in connection with this subject, could not be used in arriving at a basis for the apportionment of cost among the parties interested in abolishing any particular crossing.

Regarding the apportionment of cost, the Board of Engineers recommended as follows:

"But if the custom of employing a special commission to apportion the cost be kept up, we would suggest that it should be made permanent to that extent that the same persons should be called in all cases, in order that whatever experience is gained from year to year may be utilized."

The final summing up of the question of dividing the expense was made by the Board of Engineers as follows:

"Finally, we think that the expense of abolishing crossings should be generally divided between the railroad and the city or town, bringing in the county in special cases, and also the street railways and adjoining estates if they are benefited.

"But we do not consider it practicable for the Legislature to fix in advance the proportions to be paid by the parties interested, for the reason that in no two places that have so far come under our observation have the benefits or the disadvantages been equally divided. We would recommend that each one be divided on its own merits by some tribunal such as we have hereinbefore suggested."

The Board of Engineers made its report, as directed by the Legislature, under date of January 31, 1889.

Beside the general treatment of the subject and the recommendation as to the policy to be pursued, quite a number of special cases were considered and worked out with considerable detail by the Board of Engineers. Several of the crossings so considered have been abolished under the provisions of the law of 1890, following quite closely the recommendation of the Board of Engineers.

The consideration of the subject of the abolition of grade crossings which led to the appointment of the Board of Engineers was continued after their report was made, and, governed somewhat by the suggestions and recommendations made during several years by the Railroad Commissioners and by the recommendations of the

Board of Engineers, the Legislature in 1890 passed an Act entitled "An Act to Promote the Abolition of Grade Crossings."

Several laws had been passed at earlier dates, under the provisions of which grade crossings could be abolished, but they were not calculated to encourage the movement on a sufficiently large scale to reach the results which were by this time demanded.

Passing over the earlier laws noted, it will be seen that in the year 1890 the Commonwealth adopted the policy of a gradual general abolition of the existing grade crossings, with a division of the expense between the State, the city or town in which the crossing is situated and the railroad company. The Legislature appropriated five millions of dollars for this purpose, to be spent in ten years, the amount expended not to exceed five hundred thousand dollars in any one year.

The main features of the Act of 1890, Chapter 428, condensed, are as follows:

The Mayor and aldermen of a city or the selectmen of a town in which a public way and a railroad cross each other at grade, or the directors of the railroad company (also the Attorney-General instructed by the Governor and Council after notice to the interested parties and a hearing), may petition the Superior Court or any justice thereof. After notice by public advertisement or otherwise, and a hearing, the court may at its discretion appoint a commission of three disinterested persons.

A petition may embrace several crossings or several petitions may be consolidated and heard as one.

The commission shall meet as soon as may be. If the commission decides that alterations are necessary for the security and convenience of the public, it shall prescribe the manner and limits within which alterations shall be made and shall determine which party shall do the work, or shall apportion the work to be done between the railroad company and the city or town.

The railroad company shall pay sixty-five per cent. of the total actual cost of the alterations, including the cost of hearings and the compensation of the commissioners and auditor for their services and all damages sustained by any person in his property or for land; thirty-five per cent to be apportioned between the Commonwealth and the city or town in which the crossing is situated; providing, however, that not more than ten per cent. shall be apportioned to the city or town.

If the commission decides that any portion of an existing public way should be discontinued, it shall so specify. It shall further specify the grades for the railroad and public ways and the general

method of construction; also what land or other property it deems necessary to be taken; provided, however, that if such decision involves a change in the grade of a railroad, the approval in writing of the directors of the railroad shall first be obtained. This provision was afterwards changed, making it necessary to obtain the approval of the Railroad Commission instead of the directors of the railroad.

The commission shall return its decision into the Superior Court. The decree of the court confirming the decision of the commission shall be final and binding.

The Act provides for taking land and prescribes the process to be followed; also for the recovery for damages sustained by any person in his property or for land taken and for taking land by the city or town or railroad company.

After the completion of the work, the crossing and its approaches shall be maintained and kept in repair as follows:

When the public way crosses the railroad by an overhead bridge, the framework of the bridge and its abutments shall be maintained and kept in repair by the railroad company, and the surface of the bridge and its approaches shall be maintained and kept in repair by the town or city in which the same are situated. When the public way passes under the railroad, the bridge and its abutments shall be maintained and kept in repair by the railroad company, and the public way and its approaches shall be maintained and kept in repair by the city or town in which they are situated.

The court shall appoint an auditor, who shall be a disinterested person, not an inhabitant of the city or town in which the crossing is situated, to whom shall from time to time be submitted all accounts of expense, whether incurred by the railroad, city or town, commission or auditor. The auditing, when accepted by the court, shall be final. The court shall from time to time issue decrees for payment. The Commonwealth shall pay the proportion apportioned to it and to the city or town. The city or town shall repay in such annual amounts as the auditor of the Commonwealth may designate, interest at the rate of four per cent being charged to the city or town on the amount due.

The Superior Court or any justice thereof sitting in equity in any county shall have jurisdiction to compel compliance with this Act and with the decrees, agreements and decisions made thereunder.

If the aldermen of a city or the selectmen of a town and the directors of a railroad company agree as to the alterations to be made, the agreement shall have the same force and effect as the

decree of the court under the provisions of this Act; provided, that the Railroad Commissioners, after notice to all parties and a hearing, approve the alterations set forth in the agreement. In this case the Commonwealth shall pay twenty per cent. of the cost.

Notice shall be filed by the petitioners with the Railroad Commissioners of the entry of any petition under the provisions of this Act, and in case application shall be made for changes in grade crossings which will require, in the opinion of said Commissioners, a larger expenditure in any one year on the part of the Commonwealth than the amount provided for by this Act, said Railroad Commissioners shall have full power to decide which, if any, of the said pending petitions shall be proceeded with during the year, and no decree shall be entered under any such petition until a certificate is filed thereon by the Railroad Commissioners that in their judgment the expenditure on the part of the Commonwealth will not exceed the amount provided for by this Act.

PRACTICAL WORKING.

Regarding the practical working of the Act of 1890, everything has been as favorable as could be expected. At first the number of applications was small, and it was necessary, to pass other acts amending and perfecting the details. Some railroad companies have taken the initiative, applying for the abolition of many grade crossings on their lines. Others have waited for the cities and towns to take action, meeting them fairly and helping on the movement. In a very few cases have the companies done anything to prevent action. As far as the writer has been able to learn from the records, petitions have originated as shown in the following table, which does not, however, cover nearly all of the cases:

TABLE. VIII.

Number of Petitions.	By Railroad.	By City or Town.	By City and Railroad Jointly.	By Commonwealth.
150	59	76	15	0

Many of the above noted petitions covered several crossings each.

The petition is directed to the Superior Court, and can be acted upon by any justice of this court. The Superior Court has a sufficient number of justices to insure prompt action on business of this character. The justice to whom the petition is brought, after proper notice to all parties interested, has a public hearing. If he decides that further action should be taken and that the petition is a proper one, he appoints a commission of three disinterested per-

sons. The usual course in these cases is for the representatives or counsel of the parties interested to present the names of parties who would be acceptable to them. If the justice finds these to be persons whom he believes to be suitable, he appoints them, but he is not restricted to such names, and may appoint any person at his discretion. It has been customary to appoint a lawyer, a civil engineer and one other person, but there has been no fixed rule regarding the composition of the commissions.

Under Section 2 of the Act, the court may consolidate several petitions and order the Commissioners to hear them as one, saving time and expense to all parties interested in the proceedings, and by considering the work of alterations of a group of crossings as one problem and treating them accordingly, enabling the engineers to plan the changes so that interference or useless work and expense may be avoided.

By an Act passed in 1891, amending that of 1890, the Commission is authorized to apportion the work to be done and the sixty-five per cent. of the cost among several railroads where more than one crosses the public way at or near the same point.

The commissioners are required to meet as soon as may be after receiving notice of their appointment. Usually notice is sent by the clerk of court and the members are called together by the person first named, or whose name stands at the head of the list as sent out by the clerk of the court. The commission meets and a time for hearing is determined upon. Notice is given to the principals interested and the date is usually fixed at about thirty days after the time of the first meeting, although in some instances a less period has been named.

At the hearings before the commission, the city or town and the railroad company are generally represented by counsel. In the more important cases the Commonwealth is represented by the Attorney-General or one of his assistants. Sometimes persons whose interests are affected are represented by counsel, but more frequently such persons state their own case and receive the same treatment as counsel.

In taking testimony and hearing arguments, the practice of the courts is followed, often with more latitude than the strict adherence to the rules of testimony would admit, the main object being to get at the facts bearing upon the case in the easiest way and shortest time.

The first hearing is generally held at some convenient place as near as possible to the crossings to be considered, so that all persons interested may have an opportunity to be heard. A view of

the crossings and surroundings is taken at an early stage of the proceedings, and plans of proposed changes submitted by one or more parties.

After hearing all parties who appear and desire to be heard, the commission decides whether alterations are needed for the security and convenience of the public. If in the negative, the hearing is closed and the decision reported to the court. In one case of this kind the Legislature afterward passed an Act requiring the abolition of the crossing and ordered the court to appoint a commission to decide as to the manner in which the alterations should be made.

If the commission decides in the affirmative, the hearing is continued on the other parts of the subject. First, as to what alterations shall be made, prescribing the manner and limits within which they shall be made with sufficient detail to fix definitely these questions and to prevent disputes later when the work is done.

The commission has power to order new public ways to be built in substitution for those used before, to discontinue portions of highways, to have the railroad company take land when more is needed for its alterations, to have the city or town take land where necessary for its alterations of public ways, to change the grade of public ways, to change the grade of railroads, the approval of the Railroad Commissioners having first been obtained.

In case the grade of the railroad is ordered changed, the approval in writing of the Railroad Commissioners must accompany the report when it is presented to the court.

In case land is taken or property damaged, if the parties in interest cannot agree, the owners can recover compensation by making application to the Superior Court within one year after the day of the date of the decree of the court confirming the decision of the commission. A jury will then determine the amount of damage.

When land is taken, the decree of the court confirming the decision constitutes a taking of the land. The clerk of courts must, within thirty days after making the decree, cause a copy of the decision and decree to be filed with the County Commissioners and recorded in the registry of deeds of the county in which the property is situated, also with the Auditor of the Commonwealth.

The commission also determines which party shall do each portion of the work ordered. In practice, to avoid conflict of authority and, consequently, danger to travel, the railroad company is generally ordered to do the work, or, in case more than one railroad company is interested, the commission orders all the work to be

done by one company or divides it between them, as seems best with regard to safety and economy.

The commission also apportions the thirty-five per cent. of the total actual cost between the Commonwealth and the city or town in which the crossings are situated. The law provides that not more than ten per cent. shall be apportioned to the city or town, and ten per cent. is the proportion usually allotted to them, although in a few instances a smaller proportion has been placed upon them. The proportion to be paid by the railroad company or companies is fixed by law at sixty-five per cent.

After hearing and deciding upon the above noted details of the case, the commission makes its report to the court. The report is usually accompanied by plans showing in detail the alterations ordered; also what land, if any, is to be taken to admit of carrying out the alterations as ordered. The plans are signed by the commissioners and made part of the report.

Should any of the parties interested be dissatisfied with the findings and report of the commission, they are heard by the court before the report is approved. If the report is approved, a decree of the court is made confirming the report and decision of the commission. The duties of the commission then cease.

The compensation of the commission is not fixed by law, nor has any rule regarding it been made by the court or otherwise. Each commission fixes its compensation, subject to approval of the court.

It would seem from the experience of more than ten years since the law was passed that the feature of a special commission for each case or group of cases has been acceptable and has worked well. It gives an opportunity for the court to select those persons best fitted to consider and decide each case, and the results have been as good, probably much better, than would have been reached if one fixed commission had been constituted to hear and decide all cases arising under the law.

By the provision of Section 6 of the law, the Legislature established a principle for determining the manner in which the public ways and structures as altered shall be afterward maintained. If the way crosses the railroad by an overhead bridge, the framework of the bridge and its abutments shall be maintained and kept in repair by the railroad company, and the surface of the bridge and its approaches shall be maintained and kept in repair by the town or city in which the same is situated. When the public way passes under the railroad, the bridge and abutments shall be maintained and kept in repair by the railroad company, and the public way and

its approaches shall be maintained and kept in repair by the town or city in which they are situated. This division of responsibility and cost of maintenance is on natural lines, and to each party is assigned that portion which it can best inspect or observe and for which it is best prepared to furnish material and do the work of maintenance.

The auditor provided for in Section 7 is appointed by the court, and during the progress of the work, from time to time, examines the accounts of the parties doing the work and makes return to the court. Upon the acceptance of the auditor's return, the court issues its decree to the railway company and Commonwealth for payment of their proportion of the cost. In case of an objection to any account presented, the auditor fixes a time for hearing the objection, at which time witnesses may be examined or testimony bearing upon the subject taken. Objection may also be made to the court against the approval of the auditor's returns by either of the parties interested. The court will hear the cause, and, if the objection is well founded, may refuse to accept the auditor's report and order the same changed. An appeal may even be taken to the Supreme Court.

ADDITIONAL AND AMENDATORY LAWS.

It has been found necessary since the passage of the Act of 1890 to pass others perfecting and amending it, and to pass some laws for special cases where the conditions were not the same as in the majority of cases, and where the provisions of the Act of 1890, if enforced, would work hardship on some of the parties. The most important of these laws are noted, as follows:

"1891. Chapter 33. Where several railroads are included in the petition, the commission shall have the same power as is now provided where there is but one, and may apportion the work among the railroads and shall equitably apportion the sixty-five per cent. among the several companies, and shall award the manner and proportion of each in the maintenance and repair."

"1892. Chapter 178. A city or town may incur debt outside the legal debt limit to pay for land or property taken."

"1893. Chapter 283. The Commonwealth shall pay in the first instance the amount apportioned to the city or town, to be repaid as the Auditor of the Commonwealth may designate."

"1896. Chapter 439. If in any one year the expenditures by the Commonwealth shall not amount to five hundred thousand dollars, the unexpended balance thereof shall be added to the amount allowed to be paid during any subsequent year."

During the five years after the passage of the Act of 1890 the expenditure did not nearly equal the appropriation, and the balance was, by the terms of the Act of 1890, not available for the purposes for which it was intended; hence the necessity for the amendment noted above.

The largest amount paid by the Commonwealth in either of the first five years was $407,491.72, in 1895, and the aggregate for the five years was $861,892.55.

SPECIAL LAWS.

Some of the most important special laws passed are as follows:

"1892. Chapter 433. Relating to certain crossings on the Boston and Providence Railroad. In this case it was provided that the Commonwealth shall pay forty-five per cent. of the expense. The city to repay to the Commonwealth thirteen and one-half per cent. of the whole expense."

"1892. Chapter 374. Chelsea bridge over the Boston and Maine Railroad. Five per cent. of the expense to be paid to the Boston and Maine Railroad by the street railway company and thirty per cent. by the Commonwealth. Of this each city, Boston and Chelsea, shall repay five and four-tenths per cent. of the whole expense."

This is the first instance in which a street railway company was by law required to pay a portion of the cost of the abolition of a grade crossing, and its proportion in this case was simply the extra expense incurred in keeping the railway in a safe condition for operation while the changes were being made.

"1893. Chapter 179. Removed certain crossing in the city of Worcester from the operation of the grade crossing Acts for the term of five years."

"1894. Chapter 226. Regarding alterations at Brockton. The compensation of the commissioners and expense incurred in surveying, engineering and other matters under their direction to enable them to make their report shall be part of the expense of the alterations. The New York, New Haven and Hartford Railroad Company shall do the work, and commence the same within six months after the decree of the court, and prosecute the same to final completion with reasonable diligence."

"1895. Chapter 233. In the proceedings for the abolition of grade crossings at Northampton, if the commission decides that it is necesary for the security or convenience of the public to alter, re-locate or build anew any passenger station, freight depot or other necesary structure, or re-locate a freight yard or to provide new freight yards or other facilities, or to substitute other lands therefor as incident and made necessary in their judgment by the abolition of grade crossings . . . . the commission may prescribe the manner and limits and the limit of cost within which the same shall be made."

"1896. Chapter 257. This act provides for alterations in the towns of Hyde Park and Dedham. The railroad company may operate branches and its road between Readville and Boston with electric power.

"Forty-five per cent. of the expense incurred by the railroad company shall be paid by the Commonwealth.

"The towns of Hyde Park and Dedham shall each repay to the Commonwealth thirty per cent. of the amount paid by it on account of expenses incurred in said towns."

"1896. Chapter 535. This Act provides for various changes at the freight yards of the New England Railroad in South Boston. The expense . . . . shall be paid by the railroad company, the city of Boston and the Commonwealth in such proportion as the commissioners shall decide to be just and equitable, concerning all of the relations of the parties."

STREET RAILWAYS.

There is one element which has not as yet, except in two instances—the one noted above and one more recent—been brought into the grade crossing cases as a contributor to the expense; that is, the street railway companies. When the law of 1890 was passed, and, in fact, until several years later, the street railways did not fill so important a place as they do now. With the application of electricity to railway traction and the great increase in the number and mileage of railways, great additional danger has been introduced at the crossings where the railways exist and the necessity for the separation of grades has been made much more urgent than when the comparatively small number of horse railways was to be considered.

The danger of crossing railroad tracks by electric railway tracks at the same grade has been fully appreciated by the Railroad Commissioners. No such crossing can be established without their consent, and they have not given consent without very weighty reasons. Many projected railways have consequently been obliged to wait until the public way upon which they were located and to be built could be carried over or under the railroad. In a few cases the railways have built bridges over the railroads, with trestle approaches, at or near the public way, rather than wait for the abolition of the grade crossing. In quite a number of cases the Railroad Commission has given consent for the crossing of a railroad by a railway at grade for a limited period, fixing a time within which the abolition of the crossing may reasonably be expected to be carried out.

The existence of a railway or the proposed construction of one has been the cause of quite a proportion of the petitions for the abolition of grade crossings.

It has been felt by many that the railways should contribute toward the expense of abolishing grade crossings, and bills have been introduced into the Legislature having this object, but until the last session of the Legislature nothing definite was reached toward a general law covering this subject.

In their report to the Legislature the Railroad Commissioners recommended that the street railway should be required to pay part of the expense of abolishing a grade crossing on which its tracks existed; that the special commissioners should decide the amount to be paid by the railway, and the remainder of the expense should be paid by the other parties in the same proportions as they now pay the whole cost. This seems to be fair to all parties.

It has been found difficult to establish a basis for so dividing the expense that all parties in interest shall be treated fairly. The conditions vary greatly in the various cases, and possibly each of the parties heretofore in interest desires that its share of the expense shall be lessened by the contribution of the newcomer. The conditions vary so much that it would be difficult to fix percentage of the whole cost which would be fair in all cases for the railway's proportion.

It would in many cases be a decided advantage to the railway to be made a party in interest and have regular standing before the special commission. If it should be required to pay part of the cost, it would have a right to be heard concerning the work to be decided upon by the commission.

Several street railway companies have within the last few years located their lines partly upon their own land outside the limits of public ways. By so building, it has become necessary in some instances to cross public ways from one part of their private right of way to another, thus establishing grade crossings differing but little from those of railroads. The conditions leading to danger are nearly the same in both cases, and it will probably be found necessary to place by legal enactment the same safeguards around railway crossings of this nature as have been applied to railroad crossings.

The writer has been pleased to note that in some recent locations the railway companies have recognized this element of danger and have provided for carrying their lines over or under public ways.

According to the Railroad Commissioners' report for 1902, there were, on September 30, 1901, three hundred and twelve crossings at grade of street railways with railroads. Quite a number of these crossings were, however, railway tracks crossing spur tracks of railroads away from the main lines.

AMOUNT EXPENDED.

Up to January, 1901, as shown in the report of the Railroad Commission, the Commonwealth expended for the abolition of grade crossings the amounts shown in the following statement:

TABLE IX.

Year.	Paid by Commonwealth.
1892	$87,056.29
1893	96,141.97
1894	270,485.07
1895	407,491.72
1896	874,211.81
1897	715,938.62
1898	488,981.18
1899	510,340.00
1900	925,482.19
	$4,376,128.85

Of the above amount there has been repaid by cities and towns $512,023.63; to be repaid, $864,934.97; total, $1,376,958.60, which, subtracted from the amount paid out by the Commonwealth, leaves a balance of $2,999,170.25. This, taken as twenty-five per cent. of the whole, gives: proportion of cities and towns, $1,199,668.10; proportion of railroads, $7,787,742.65; a total expenditure under the Act of 1890 of $11,986,581.

UNDER SPECIAL ACTS.

In addition, there has been expended under special acts up to January 1, 1901, by the Commonwealth for the abolition of grade crossings in the city of Boston and the towns of Hyde Park and Dedham the sum of $2,687,930.55. Of this the proportion of the Commonwealth, after deducting payments which have been or will be made by the city and towns, is $1,881,551.39, making a total of expenditure for this object between the time of the passage of the Act, in 1890, and January 1, 1901, $17,904,655.91 under the provisions of the Act of 1890 and special acts.

The total number of crossings abolished, as given by the Railroad Commissioners in their report for 1902, is 243. In the same report the number of grade crossings still existing is given at 2001.

There are still in existence a number of the most dangerous grade crossings, some of them among the most expensive to abolish.

The aggregate capital stock of the forty-five railroad corporations reporting in Massachusetts June 30, 1901, was $210,305,-885.72, but of this amount quite a large proportion is of corporations having a large proportion of their railroads in other States. The capital stock of railroads in Massachusetts, that is, the capital stock of railroads entirely within the State added to the proportion due to mileage in the State of those railroads which are in more than one State, is about $97,000,000.

The Railroad Commisioners, in their report for 1902, stated as follows:

"Early in the year the fund provided by the Commonwealth to meet its share in the expenses of abolishing grade crossings of highway and railroad was practically exhausted."

The words "early in the year," of course, refer to the year 1901.

In consequence of the expenditure of all funds available under previous acts, the Legislature during its last session passed additional acts providing means for continuing the work of abolishing grade crossings and dealing with some features of the work not previously provided for.

Chapter 440, Acts 1902, approved June 4, 1902, makes several important changes in the provisions of the Act of 1890 and the acts passed at later dates amending the same.

"The directors of a street railway company having a location in that part of the public way where such crossing exists" are given the same rights of petition as the city or town authorities and directors of railroads have heretofore had. "Upon all petitions hereafter filed and upon all now pending on which no commission has been appointed . . . . such street railway company shall be made a party."

The actual cost to the street railway of changing its railway and location to conform to the decree of the court is made part of the cost of abolishing the crossing. The commission may assess upon any street railway company duly made a party to the proceedings such percentage of said total cost not exceeding fifteen per cent. thereof, as may in the judgment of the commission be just and equitable. The proportions to be paid by the railroad and city or town remain the same as in the previous acts, thus relieving the Commonwealth of the part assessed upon the railway. Provision is also made for the repayment by the Commonwealth to the railway company of the amount so paid by it if in the future its location is revoked without its consent, the Railroad Commissioners to decide

whether such repayment shall be made. The special commission may change the location of a street railway.

Chapter 440 also authorizes the expenditure of five million dollars by the Commonwealth, the amount to be paid in any one year not to exceed five hundred thousand dollars; but if in any one year the amount expended shall not be five hundred thousand dollars, the unexpended remainder shall be added to the amount to be paid in any subsequent year.

"No final decree shall be made by said Superior Court upon any report of commissioners setting forth a plan for the abolition, discontinuance or alteration of a grade crossing, adopting or confirming such plan or authorizing any expense to be charged against the Commonwealth, until the Board of Railroad Commissioners, after a hearing, shall have certified in writing that in their opinion the adoption of such plan and the expenditure to be incurred thereunder are consistent with the public interests, and are reasonably requisite to secure a fair distribution between the different cities, towns and railroads of the Commonwealth, of the public money appropriated in the preceding section for the abolition of grade crossings, and that such expenditure will not, in the judgment of said Board, exceed the amount provided under the preceding section to be paid by the Commonwealth."

The work of abolishing grade crossings in this State has proceeded in a manner which promises to remove, within a few years, a large proportion of those most dangerous to public travel. The large expense involved has made it necessary to move with some degree of deliberation. From the figures given, it will be seen that the interests of both taxpayer and stockholder require that care be used to avoid undue expense in carrying out the work. The decreased number of casualties at crossings already shows that the work done is producing the results hoped for.

DISCUSSION.

Mr. John W. Ellis.—In providing for the abolition of grade crossings, the general plan to be adopted is a matter of judgment, dependent upon local conditions.

I am hardly willing to agree with the writer of this paper, that the course which has been pursued in the State of Massachusetts is the most equitable and justifiable one, more particularly in the matter of definite proportions, and having an independent or different commission upon every petition for abolition of grade crossings,—for that is what the purport of the law is.

I have often thought that it would be much better if the Governor and Council appointed a continuous commission, the same as the Railroad Commission, who by their experience could so classify

the different petitions that their decisions would be more equitable to all the parties in interest.

Very often the petitioner is the railroad company, and solely because they wish to make important improvements, either new terminals or additions to the freight facilities, which are of particular benefit to the railroad company itself; also, often the petitioner is the city in like respect: for that reason, in a number of cases I have thought that the proportions ought not to be invariably the same.

The law or act in this State has nearly always fixed the proportions, and in the matter of the great progress of the street railroad, which, as the writer has stated, has increased so far beyond anyone's conception since 1890 that they have become a party in interest, and one to help pay for these improvements.

In Chicago there is no grade crossings commission, but a grade crossing commissioner is appointed.

At the time when the Chicago act (?) was passed, it was thought that it gave too much power and too much authority to one person. The ordinance of the City Council defines distinctly just how much the railroad is to be raised or depressed and definite grades of the streets. The commissioner sees that the requirements of the ordinance is complied with by the railroad, which does all the construction work.

The railroad company pays the whole bill except the land damages, and those in the city of Chicago are not settled yet. I understand they have accumulated for a number of years and are still on the docket.

Another question frequently occurs, particularly here in the East. The two principal parties, the railroad and the city, consume most of the time at the hearing before the commission.

The abutter, the owner of the property, is allowed to be heard, but he does not have very much voice before the commission; but, perhaps that is just, for he has his remedy at law, before a jury, and usually comes out better than either the railroad company or the city.

I have often wondered whether, if the State of Massachusetts had not fixed these proportions at the time it did in the inception of its law, but had waited until this time, they would have fixed the proportions as they are to-day.

THE PRESIDENT.—Mr. Ellis, what is the proportion in Rhode Island?

MR. ELLIS.—There is no law in Rhode Island. The proportion has always been fixed by amicable agreement, but I do not think

that the railroad companies have ever paid over 50 per cent. In fact, I know that, in the city of Providence, in the matter of accomplishing certain terminal facilities within the city limits, they went so far as to pay nearly 50 per cent. The whole thing, practically, was done by the railroad company, but a distinct agreement existed, between the railroad and the city, that they should assume certain expenses in regard to grade damages which really amounted on preliminary estimates to about 50 per cent.

I have recently had some experience in Detroit, where the whole matter is arranged by ordinance, about the same as in Chicago. The desirable growth for a railroad is about the same, but the growths of the streets of the cities vary.

In Fall River, a tide-water city and very hilly, nearly everything is received at sea level.

For a city like that the maximum grades are entirely different from those at Taunton, only a few miles distant.

Detroit is entirely flat, and in that case you will find the railroads protecting the interests of the manufacturers to such extent that they don't think it wise that the streets should be depressed adjoining manufacturing property contiguous to a railroad, and in that city the manufacturers have redress at law. They get very large remuneration for any change in the grade of streets. The city itself is willing to be subject to what we would call a maximum grade for the depression of streets rather than have the manufacturers put to any trouble.

Mr. J. W. Rollins, Jr.—Some years of work on grade crossing schemes in making plans and decrees have shown some interesting results of the law as now on the statute book.

The matters of land takings and of changes of grade of highways seem incomplete in that no notice is served on owners of such takings or changes of grade; so that, unless the parties interested go to the hearings and there learn of the changes proposed and as to how it will affect their property, they will be in ignorance of any change until the work actually begins; and, if this is not within a year of filing of decree, they will have no standing in court and must accept such awards as the city or town or the railroad company may make.

In railroad locations where land is taken, a plan of such taking must be given to the owners, and then the owner has three years within which to bring suit.

At Brockton a man unknown to the railroad company owned a piece of land within the limits of the new freight yard, and this land was taken by decree. A year later it was graded down 25 feet

and its original appearance was entirely changed. The owner turned up about this time and wanted his land, but it wasn't there, and he had to take the award of the railroad company, which, doubtless, was a fair one.

Again, on Ruggles Street, Roxbury, the street grade was changed some 5 feet at railroad crossing, and of this change owners on the street were not notified. Two years after the decree was filed the work was done, the owners had no redress and to-day some of the property affected is left above the street grade.

Another interesting question is, Who shall do the work of changing both the railroad and the streets? The railroad company, paying 65 per cent. of the cost, and fearing to allow city authorities a chance to work "politics" into the scheme, wants to control all the work, while, on the other hand, the city wishes to do for itself the work on its own streets. One large scheme, after long and warm discussion, was settled, and I think wisely, by allowing the city engineer to make plans and specifications for the surfacing of the streets, which work was contracted for by the railroad company and actually done under the direction and supervision of the city engineer. My opinion is that most railroad engineers have enough troubles of their own and are willing to shift the matter of street grades and construction, sewers and the like, onto the city engineer.

One case coming to our notice was where the decree provided that the town should do the work on the street, which work was particularly heavy, being hard digging and some rock work. The town put onto the job, at $2 per day, all its delinquent taxpayers who were willing to make a bluff at working off their taxes, and the result was that the grading cost about $1 per yard, while it could have been contracted for at 35 cents. The railroad company objected to the bill, but I think they finally paid it.

Another point is the division of cost: the 65, 25 and 10 per cent. according to law always seemed to us to involve, in many cases, an excessive charge on the railroad.

For instance, at a grade crossing on the Providence Division of the Old Colony Railroad, a main thoroughfare, the street was wide and straight and the railroad was a tangent for miles. The crossing was not a particularly dangerous one, and to change it meant the abandoning of a piece of the highway for half a mile and building a substitute road crossing the railroad some 300 feet to one side of the original crossing.

An electric road came along and wanted to cross, having gotten location in the highway, and I think the electric company and the

steam road had a scuffle on the site to prevent a crossing. The railroad company petitioned at once for the abolition of the crossing and met with the greatest opposition from the town authorities and the land owners on the street. They wanted a grade crossing, with electric cars using it. Finally the commission decided, for the "safety of the public," that the grade crossing must go, and the railroad company at once pushed the work to a completion. This seemed to be a case where the imposition of 65 per cent. of the cost on the railroad was unjust, inasmuch as work was done to avoid an electric railway grade crossing.

Under the existing law, the conditions would be changed as to this division, and quite justly, making the street railway share in the expense.

Sometimes crossings are abolished, at the request of town or city, where the railroad interest is small. On the other hand, the railroad at times wishes to get rid of crossings in which the towns have no interest, and we think that, in some such cases, the commission has apportioned to them only 6 or 8 per cent. of cost.

In some of the first big schemes undertaken the railroad company met with this sentiment from the towns: "We pay only 10 per cent. of cost, and that in ten annual payments to the Commonwealth, and so we do not care about cost; if you will give us what we want, you can do as you please with your railroad."

Under this trade, valuable improvements were made by the railroad; new streets laid out; new pavements, etc., put in by the city, and all charged to the scheme, and the Commonwealth not appearing at all in the proceedings nor objecting to any bills which the two other parties agreed to, the accounts were approved by the auditors.

In this way, schemes estimated to cost $363,000 by the Grade Crossing Commission cost $2,300,000, while one estimated at $1,350,000, cost nearly $4,000,000. These discrepancies were doubtless due in part to the fact that more crossings were abolished than were originally estimated upon.

This liberal policy of the State seems to us to be a good one, in that under it the work was made *complete,* and suitable provision was made for both the railroad and the city for future development.

When building the Massachusetts Central Railroad through Waltham, in 1880, the railroad company did not think it worth while to ask for a location crossing a certain street at grade, in view of the stand then being taken by the Railroad Commission

against such crossings. As a result, the location was filed to cross under the street, *raising* it some 16 feet.

It was one of the most beautiful streets in town, bordered by large elms, and to raise it meant a perpetual eyesore to that part of the town, besides being a nuisance to traffic to go up a 5 per cent. grade on each side.

Some interested citizens got up a mass meeting and so strongly protested against any change in the street that the Railroad Commission relented and allowed a grade crossing: *to be abolished later.*

This seemed to be a common sentiment in those days regarding high bridges over tracks or tunnels under them, and the people generally seemed to be willing to take their chances on the crossings rather than go up or down, over or under the railroad.

A question now interesting cities is: What kind of a bridge will the railroad company build? All the strong adjectives in the dictionary have been applied to a "plate girder" bridge, the most common type in use, and strong efforts are made for stone arches, "esthetic features," and something pleasing to look at.

The "chromos" made by artistic engineers of stone arches for certain crossings would make a suitable offering to the St. Louis Exposition in 1904,—some of them more suitable to be exhibited than to be used as plans for construction.

Once, at a grade crossing hearing, a leading railroad attorney asked me what I was there for. I answered, "To try to show the commission that stone arches are cheaper and better than steel bridges." He answered, "The railroad companies oppose arches while they should build them, they making a permanent roadway, and one over which any train load can run; no painting, loose rivets, etc.; but, all the same, they build steel bridges."

On the other side, the cities demand the arches simply on account of the looks, for a bridge will give them more headroom on the sides of the streets and more light under the tracks, but their hideous appearance overbalances these considerations and they ask for arches.

The question of construction in grade crossing work presents many intricate problems for engineers and much interesting work. A president of a New England railroad entering Boston with a double track and heavy traffic is reported to have said: "If we are to abolish the crossings we must abandon our road while the work is being done." On a location about 50 feet wide on this same road a double track was maintained two years, with an additional train service, and the road raised 20 feet in the air, being

held by retaining walls whose bases alone took up over 20 feet of the width of location.

Engineers glory in such achievements, when accomplished, forgetting then the worry (and worse) over the question whether everything is clear of traffic or strong enough to carry it; whether some idiot will drop a stone on the track or let a derrick fall across it. When life is involved to such an extent, the engineers often wish that they, too, could strike for an eight-hour day of work, and, after that, seek recreation in the "bosoms of their families," or "improve their minds" as other eight-hour men do.

But the profession required the assumption of all responsibilities, and meets them, small or great, as they come.

Mr. H. Bissell.—I think one of the greatest faults in the grade-crossing law as it stands is in the matter of settling for damages to property of abutters.

Prof. George F. Swain.—I fear I can add nothing of value to the discussion of this paper, but I feel greatly indebted to Mr. Turner for preparing it. It is a valuable summary and discussion of the whole subject. One point, however, comes to my mind in relation to the relative advantages of permanent commission, as compared with the appointment of a separate commission for each case. If the Legislature had not fixed the proportions which the different parties should pay, I should certainly agree with Mr. Ellis that it would be much better to have a permanent commission which should direct or decide with reference to all such work. The fact that the Legislature has fixed proportions which the different parties must pay, however, makes the appointment of a special commission in each case justifiable, and I agree with Mr. Turner that the results of this method have been good. It is undoubtedly true that the relative proportions to be paid by the parties ought in fairness to be varied in different cases; but if they had not been fixed, a new element of uncertainty would have been added in each case, and it strikes me that perhaps on the whole it was wisest to fix these proportions once for all. What the results would have been if a permanent commission had been appointed can, of course, only be conjectured; but even a permanent commission is not really permanent, as its membership changes from time to time on account of death, political exigencies, etc. For instance, the Railroad Commission has completely changed about twice in the last twelve years. The Board consists of three members, and in the last twelve years there have been nine persons serving upon it. Of course, the records of a permanent commission are permanent and valuable, and its traditions endure to a certain extent; but any change in

membership is likely to be accompanied by some change of practice or policy. It does not follow that its practice must be absolutely unvarying.

Mr. William F. Williams.—I am glad that Mr. Turner has left one subject for me to say a few words upon without assuming to take issue with such a very interesting and valuable paper. He has stated that, in nearly all grade crossing cases, the railroad has been in sympathy with the movement and has offered no objection to the alterations sought for. New Bedford happens to be one of the exceptions, inasmuch as we have had to meet a very vigorous opposition from the railroad to the adoption of any plan for the elimination of our crossings.

The New Bedford Commission was appointed in 1894 and it has not yet reported. The city has done everything in its power to furnish the commission with all the information required to enable it to report; but, so far, without success. While our experience may have been unusual, it is evident that the law has not provided for such a contingency, and it is of sufficient importance to merit some consideration.

The law evidently intends that the "security and convenience of the public" shall be the paramount issue, for it provides that if the commission decide "that the security and convenience of the public require the alterations" then "they shall prescribe the manner and limits thereof," etc. There is no room for personal discretion in the latter declaration, and why should there be, after it has been declared that "the security and convenience of the public" require a change? How can you differentiate this question in various localities on the basis of cost and operation, which the railroad would have you believe are the controlling factors? This is the law as it stands to-day, although, in fairness to the railroad, which, in the first instance, pays the larger part of the cost of the changes, there should be some discretion allowed in determining the time when the work shall be done. On the other hand, it is manifestly improper that even a conceded deficiency in the law should be an excuse for not executing the law as it stands, instead of prolonging the investigation indefinitely at considerable expense to the city and with great uncertainty and loss to the citizen whose property may be involved in the proposed changes.

It has been suggested that better results might be obtained if there were a permanent grade crossing commission whose whole time would be devoted to this one subject. Personally, I do not believe this is the best way. I think the law itself should provide for a reasonable conclusion to every investigation. It is true that

in time a permanent commission would accumulate a large amount of valuable information, which would be easily available and could be readily applied, as there is a certain similarity in the difficulties which will be met in the various cases. But there are only a few ways of abolishing a grade crossing, one of which must fit every case. There will be local features that will have to be worked out differently in each case, but they can all be met. None, I think, are insurmountable, and there will seldom be any engineering reason why they cannot be met and decided in a reasonable length of time, say two or three years.

The general plan having been determined, the question as to when the work shall be done might well be a separate feature, as no doubt it might be made a great hardship to the railroad. I believe that the time within which the work shall be done should be fixed by the commission so as not to embarrass any of the parties in the case, but the report itself should be concluded and accepted, and then any citizen whose property is involved would know with certainty what is to be done. In New Bedford we have a considerable amount of private lands involved in the proposed alterations, and the owners of these lands do not know whether the changes will ever be made or not, and, of course, they are more or less deterred, if not actually prevented, from making improvements.

It has been stated that the cost of grade crossing work in the past has included many items not properly chargeable to the fund, and that the cities and towns have been the principal offenders in this matter. No doubt the general statement is correct, but to say whether the railroad or the municipality received the greater benefits would require a careful examination of the expenditures in each particular case. It is a fact, however, that municipal officials are beginning to realize that the expense to cities and towns is not all included in the 10 per cent. fixed by law. Furthermore, the 25 per cent. advanced by the State must eventually come out of the cities and towns, and if the railroad's 65 per cent. is ever liquidated, the major part will of necessity come from the same source.

Recent reports and pending investigations show a very decided disposition on the part of all to restrict the cost, irrespective of the law. Nevertheless, there are cases where a strictly literal observance of the law will so restrict the design and scope of the alterations that they will not be acceptable to either the city or the railroad. Where radical changes in existing relations between streets and railroad are unavoidable, they must be made in a spirit sufficiently broad to provide equally as good facilities for

the transaction of business as now exist, and to fairly anticipate the needs of the future.

I cannot resist replying to one remark made by Mr. Rollins in relation to the manner in which certain grade crossing work was performed by some city or town. Perhaps it is because I am in the city's interest that I resent the imputation. I am positive that very few, if any, of the municipalities of Massachusetts would put on their pay-roll delinquent tax-payers simply to take advantage of the opportunity to enable them to pay their taxes at the expense of the railroad and State. While it might be done in a town, there are various reasons, political as well as legal, why it is impracticable in a city. I might point to the fact that many cities and towns in Massachusetts do a great deal of their own work. The city of New Bedford, for example, does not contract any of its street or sewer construction. I believe the actual cost of such work in New Bedford will compare favorably with contract prices for similar work anywhere in the State. A city which does its own work will have a plant which in itself represents not only a large investment, but the acquisition of considerable knowledge in the operation of the plant. It is hardly fair, therefore, to insinuate that a city, which can perform its own work at reasonable prices is not competent to do the same work in a grade crossing alteration simply because there are other parties to its payment.

Mr. Robert R. Evans.—One point which has been raised in the discussion of Mr. Turner's paper suggests to a city engineer another point of view from that which has been taken.

I do not think that the readiness of the city, which has been commented upon, to consent to almost anything which adds to the cost of the work, for the sake of improving it, arises from the fact that its share of the expense is comparatively small and is made to seem even smaller by a division into ten annual payments, but I do think that, within reasonable limits, it may be justifiable and proper for other reasons.

If the work is carried out under a too rigid observance of the strictest economy in the cost of construction, and if the bare needs of travel only, on both streets and railroad, are considered, the general appearance of the work is very sure to suffer, and quite probably, also, the convenience of the inhabitants of the city, in their use of the streets and railroad.

These matters may be of little consequence to the railroad company or to the State, but they are of great importance to the city; and the mere fact that the city pays but 10 per cent. of the cost of the work should not be a sufficient reason for forcing upon

it a construction which permanently disfigures its streets or unnecessarily discommodes its citizens if these objections can be met by a reasonable increase in the cost of the work.

The city should give great weight to these considerations when carrying out any permanent work, and a disregard of them works injury, and, in the immediate vicinity of the work, cannot but result in lower real estate values and a corresponding decrease in revenue.

Prof. C. Frank Allen.—The suggestion has been made by one of the previous speakers that while the city and the railroad are both represented at the hearings, as a rule the State seems to have no representative, and that it sometimes has appeared that the interests of the State were not sufficiently protected. It is very possible that this may be true. I have been told very recently by the Superintendent of one of our railroads that many items of a sort that used to go through as charges to the grade crossing abolishment are now held up because the Auditor intervenes and refuses to allow items of a sort that in some previous cases had been allowed. There appears to be a general attitude different from that which previously existed, but whether this simply means that certain auditors of late have been more than usually careful I have no means of knowing. It certainly is a matter of considerable difficulty to know just what items should be allowed under present laws in case of the abolition of grade crossings. Oftentimes the simple abolition of crossings could be accomplished at very slight expense, and the actual abolition is sometimes accomplished at an expense manifold more,—five or ten times as much. It does not necessarily follow that the larger expense is not justified. If the conditions, both as to the railroads and highway, needed no change, the lower cost would be sufficient. But what brings about the application for the abolition? Possibly it is the case that the traffic on the street has increased so that some changes need to be made for betterment of the street conditions. It may be that the railroad is contemplating putting in additional tracks, so as to have four tracks instead of two. It is rather unwise to go into new work of that sort unless the whole matter can be cleared up. Possibly, instead of a scheme for four tracks, it may happen that the railroad finds occasion for yards and other improvements in some neighborhood, and the necessity for work of that kind has been the direct cause of the petitions being sent in at that particular time. Then the abolishment should leave room for such changes. It must provide opportunity for these extensions, for a large number of tracks, for a yard, or such other improvements as are necessary.

There may be required a long and expensive bridge to cover these. In such a case it may be proper for the cost of the abolition to include the cost of the additional yard, but there is, of course, opportunity for difference of opinion as to that. Is there not some excuse for claiming that the abolition should cover whatever is necessary to allow the yard to be put there if the railroad pays for the yard? I am not speaking of those cases, if there are any, where the cost of abolition actually has included complete payment for a very much improved yard, but I am raising the other question of where a yard is necessary and where the abolition necessitates, in some fashion or another, the taking care of the problem in such a way as to provide for improvements which are contemplated.

It becomes a very difficult matter for an auditor or for a commission to determine just what should be allowed, as a part of the cost of abolition, of matters that should be paid in part by the railroad, and in part by the city, and in part by the State. It is quite easy to say, of course, right away that the work ought to be done only in the simplest way, and yet it is not altogether clear that this is fair.

I have in mind the case of a crossing in Ohio where a grade crossing had been abolished. I don't know under what law, but the grade of a street was raised in front of a large tract of land owned by a man prominent and powerful in municipal politics. The building of this embankment in front of the land produced a most unfavorable impression upon the owner, and, as a result, action was taken by the city government, under the laws that prevailed there, so that it was decreed that the bridge should be taken down and the work of abolishment completely undone. The railroad fought the case for all it was worth, and carried it through all the courts it could, but was constantly beaten. As a matter of fact, through a slight technicality or accident the bridge finally was not removed. The man with political power died, and the pressure for the change was entirely removed. This was a case where the grades after the abolishment were somewhat better than before the abolishment, or than they would again be after the abolishment had been undone.

I am certainly very glad that we have Mr. Turner's paper, so we can find at hand very many things it would bother us seriously to hunt up, and also some things, specially within Mr. Turner's knowledge, that we might not be able to find at all.

Mr. Henry Manley.—I am very glad that some of the highway people have taken a part in this discussion. In the separation of grades between a highway and a railroad there are two parties

to the divorce, and the subject should not be considered exclusively from a railroad point of view.

I have listened with pleasure to the very perfect historical statement of the movement in Massachusetts that Mr. Turner has given us, but when I thought that he had thoroughly cleared the ground, and had stated and discussed, with admirable clearness and precision, the legal and financial points involved, and was ready to attack the engineering phases of the subject—the paper ended. The legal and financial questions I shall contend are clearly within the reasonable province of the engineer, but I was a little disappointed that the same clearness and precision could not have been utilized in discussing the engineering questions that have arisen during the progress of the work already accomplished.

It seems to me that from the experience of the State of Massachusetts there might have been evolved some general principles which would be of interest; for instance, we have two contrasting examples in the greater Boston of abolition of grade crossings of considerable magnitude,—those upon the Boston and Providence Road and those upon the Boston and Albany, where opposite views were taken. In one case the railroad, as left, forms a dyke through the country which is not a pleasing thing to look at from the outside; in the other case the road is sunken and has disappeared. In other ways the city is attempting to beautify itself, and it would seem to the looker-on that whenever a railroad may be depressed and thereby obliterated from the landscape it would be much preferable to elevating it above the general surface.

In some recent decrees there is one feature which has appealed to me, in that the work to be done has been divided and the construction of the surface of the highways has been left to the city authorities. It seems to me that the people who have to maintain these structures should have something to say about the method in which the work is done. I think the ordinary municipal engineer who, without previous experience, attempted to build a railroad would not give satisfaction to the railroad corporation, and I am equally certain that the average railroad engineer is out of his element in building highways.

It has also seemed to me that the general powers of the commissions might be enlarged to cover, in addition to the particular crossing or crossings which it is desired to reform, the general subject of the future relations of the railroad in question to all highways, whether already built or in contemplation or which will inevitably be required by the growth of the highway system within a reasonable distance of the starting point, thus assuming that all

grade crossings will be done away with sooner or later and furnishing a basis for consistent action in future improvements by both public and private enterprise.

Mr. Bissell.—I should like to remind Mr. Manley that the highways are to be left in as good condition as we find them.

Mr. Manley.—The decree may read that way, but if they should be left in relatively as good condition as the railroads are left, I think there would be no cause for complaint.

Mr. Ellis.—Pardon me for saying a few words in correction. I did not intend to give the wrong impression about the appointment of the commission. My idea of a permanent or a continuous commission by appointment was to have the proportioning left to them in all cases.

Take the special act which was passed on the Boston and Providence Railroad from Forest Hills to Boston. Since this road was completed, its traffic and the speed of its trains have so increased that it would be impossible to maintain service with grade crossings and still have proper use of the streets of the city. The proportions there should be different from those in other cases.

Also, in an isolated case where it would not cost over $12,000 to make the change,—the cost of maintaining the crossing, planking, electric bells, flagmen, etc., at the rate of 4 per cent., is such that it would pay the railroad to do it itself.

In my own experience on the Providence and Worcester Railroad, the work was done without asking any aid from the town, city or State. The proportioning should be left to the commission.

As to the arches mentioned by Mr. Rollins, I believe in arch construction, and I regret that arches have not been used in the city of Fall River, where there is so much granite, which has only to be teamed down hill. It seems to me a great mistake in point of engineering that such construction is not insisted upon.

I believe that a permanent commission would have better results, and permanent results. We all know that if we make a mistake the sooner it is corrected the better it is for all parties.

Mr. G. R. Hardy.—About granite at Fall River, I may mention that the contractor is drawing granite for Fall River from Fitchburg and Whitingsville, Mass.

Mr. Fred Lavis.—I may add that two arches are about to be built on the Fall River work.

Mr. Ellis.—I am very pleased to hear it.

Mr. Frederick Brooks.—It has been made evident that the railroad companies are guided by competent advisers, and that the municipalities are. As to the poor old Commonwealth, which

has been referred to once or twice, I may mention what was said by a witty railroad lawyer in one of the earlier cases under the general law. The Attorney-General's office was represented at the hearings by three different gentlemen. As to one point in the interpretation of the law the counsel for the railroad said that it did not appear that the Attorney-General himself had any particular opinion, but that when he wished one view to be set forth he had the First Assistant Attorney-General represent him, and when he wanted the opposite view taken he sent the Second Assistant Attorney-General to speak for the Commonwealth.

Mr. I. M. Story.—So far as the State is concerned, the Attorney-General has not appeared during the last ten years for the reason that it was supposed that the railroads and the cities could get along very well without him. But the cities and the railroads have both shown such a desire to increase what one might call their betterments that the State has now stepped in. I think hereafter the Attorney-General will appear and look out for the interests of the State. I am quite sure that this is the position of the present Attorney-General.

Mr. Williams has spoken about the delay in the New Bedford matter. I think he will find that the question of betterments has caused the delay. It has caused trouble in a great many cases because the law establishes the percentages to be paid by each party,—a very great weakness in the law. The percentage should be fixed by the commission in each case. Then, if betterments were to be made, as most assuredly they would be, that would be taken into consideration in determining the percentages. Then if the city wanted a new street they could put it in and pay for it; if the railroad wanted a new freight yard or other additions they could get them and pay for them. Now, if one of the parties sees that the other party wants new accommodations, there is objection and consequent delay.

Mr. W. O. Webber (by letter).—In discussing Mr. Turner's paper on the abolition of grade crossings regarding the statement that "the results have been as good, probably much better than would have been reached if one fixed commission had been constituted to hear and decide all cases arising under the law," I would like to say that, while there is little question that the feature of a special commission for each case or group of cases has been acceptable and has worked well, I do not think it has been proved conclusively that the results which might have been obtained from one fixed commission would not have been better. While it is true that under Section 2 of the Act of 1890 "the court may consolidate

several petitions . . . . and by considering the work of alterations of a group of crossings as one problem . . . . plan the changes so that interference or useless work and expense may be avoided," there is still a question in my mind whether this provision would enable a separate commission to treat any group of crossings as intelligently and as economically as if the matter were taken into consideration in connection with the next adjoining or subsequent crossings, bearing indirectly, but none the less influentially, upon the group of crossings in question. And, also, it is conceivable in my mind that the members of such special commission would have learned, once for all, and by reason of a study of a great number of cases and simplified methods have adopted certain almost necessarily foregone conclusions. For instance, almost all large aggregations of public highways and railroads are in thickly-settled communities. Thickly-settled communities are almost always in close proximity to streams or ponds of water. Streams or ponds of water are of necessity almost always situated in valleys or low-lying grounds. Railroads, therefore, almost always descend into and rise out of thickly-settled localities.

In the separation, therefore, of grade crossings, the elevation of the railroad tracks is almost always followed by a reduction of the gradients of the railroad, which is distinctly beneficial to them.

From an engineering point of view, it is always cheaper to raise a railroad than to depress it. A railroad can in almost every case be raised without the interruption of traffic over its lines. On the contrary, if a railroad is to be lowered, it is almost impracticable to do so without stopping traffic or building a detour around the entire location during the period of depressing the tracks.

It has been found that railways require less change of grade when elevated than when depressed; consequently, the cost is less.

Retaining walls cost less for an elevated railroad than for a depressed railroad. The tracks are more easily kept clean of snow, and surface drainage is more easily taken care of with the elevated than with a depressed track. Considerable discussion has been held in times past as to the disadvantage in loading and unloading freight which would be consequent upon the elevation of railroad tracks through a manufacturing center. In almost every case which has been thoroughly tried out in this State, a relocation of freight yards has partially proved this problem. There is no question that all materials in bulk can be unloaded more cheaply from an elevated track than from a track on the level, and it is the opinion of the writer that many factories would find it just as

convenient to have a spur track entering their premises and buildings on the level of the second floor as on the ground level, for almost all manufacturing plants are equipped with power elevators. The ground floors are almost always pretty fully equipped with heavy machines requiring foundation, and the establishment of assembling and erecting floors on the second story would in many cases require less handling of materials and in better lighted rooms than if on the first floor.

The annoyance to the community from gases, cinders and smoke is much less from an elevated track than from one on the level or depressed, so that almost every argument is in favor of elevated steam railroad tracks in the separation of crossings.

The objection, from an æsthetic point of view, that railway viaducts are necessarily unsightly is not well taken. It is quite true that most of our American engineering structures are not artistic, but they could be made so at a very slight additional expense, and the writer looks forward to the time when railway viaducts and even steel bridges may become objects of pride and ornamentation to a community rather than an eye-sore.

The rapidly growing increase in the use of electric street railways, establishing communication between small communities, also has a bearing on this point, for the reason that such intercommunication will result in the steam railways being used for long distances only. It is, therefore, less burden to the community to climb up occasionally to the elevated steam railroad station, and be enabled to take the electric car on grade. Undoubtedly the separation of highway and electric railway grades will also become of vital importance, and here again much consideration must be given to the accommodation of the many as against the convenience of the few.

The street railways must also expect to bear their share of the burden of the separation of grades in connection not only with the crossing of steam railroads and electric roads with highways, but also with the crossings of highways by the electric railways at grades. Electric railways and steam railways should never be allowed to cross at grade, even for a limited period, and the recent large number of accidents caused by the electric railways and teams at highway crossings at grade leads me to believe that there is no reasonable excuse for such crossings.

Electric railways should not be built in public highways nor allowed to cross public highways at grade if otherwise possible.

The construction figures of the Northampton branch of the N. Y., N. H. & H. Road has convinced me that the cost of con-

struction of a railway, whether steam or electric, is no greater without grade crossings than with them, and I do not believe that the necessities of any railroad are sufficient to justify the latter method of construction.

These points can be duly impressed and thoroughly learned only by long, comprehensive and far-reaching study of all of the conditions; and for this reason, if for no other, I still believe that the permanent commission would be productive of better results in the long run, and for all time, than a special commission in each case or group of cases.

Mr. E. K. Turner (by letter).—It is a pleasure to know that the paper furnished a foundation for a discussion covering so many interesting points. Possibly as much has developed in the line of engineering as would have been the case if the paper had taken up this part of the subject more fully, as was so pleasantly suggested by Mr. Manley.

Mr. Geo. A. Kimball (by letter).—Mr. Rollins, in his remarks in regard to the abolition of grade crossings in Boston and Brockton, calls attention to the difference between the actual cost of the improvements and the estimated cost as found in the report of the Grade Crossing Commission. As a member of that Commission, I wish to state that it estimated the expense of the abolition of grade crossings as strictly for that change alone, not including any improvements to the railroad or street, while the actual expenditures made in Boston and Brockton included additional tracks, new stations and better terminal facilities for the railroad companies, new and better streets and improved drainage facilities for the cities; all of which are great improvements both for the railroads and the cities, but, in the opinion of the Grade Crossing Commission, were not properly chargeable to the abolition of grade crossings. In general, the same comments may be made in regard to many of the crossings which have been abolished during the last few years. Most any improvement that the cities and railroad companies could agree upon has been charged into the cost of the abolition of grade crossings.

OBITUARY.

James Spiers.

MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

THE Technical Society of the Pacific Coast has lost one of its most valued members in the death of James Spiers, the President of the Fulton Iron Works, at San Francisco.

From the very first beginning of the Society, Mr. Spiers connected himself with it, and for years remained an active and energetic member, holding the office of director and that of treasurer for many consecutive terms. Of recent years, his health having failed, he no longer could give the Society any time or attention, but there were occasional communications from him that indicated that he never had lost his interest in the work of the organization.

The members of the Technical Society take this occasion to express their sympathy with the family of the deceased and to show that both as an engineer and as a man, James Spiers is not and will not be forgotten by the many colleagues with whom he came in contact. All mourn his loss and not one who has had the pleasure of knowing him will ever forget his kind face and his warm and genial manner.

The following synopsis of his useful life has been kindly furnished to the Secretary by Mr. James Spiers, Jr.:

James Spiers, a descendant of old Huguenot and Covenanter families, was born in Scotland in 1836. He showed early in life an inclination for mechanics, becoming at the age of twenty-one, the successful manager of a large foundry in Edinburgh. In 1864 he resigned from that position and came to America, intending to settle at Vancouver, B. C., but deciding in favor of San Francisco upon the advice of Mr. Risdon, of the Risdon Iron Works. After spending three months in studying the conditions for mining machinery on the coast, he took the position of general superintendent of the Miners' Foundry, which he held three years, then became a member of the firm of McAfie, Spiers & Company, subsequently combining with the Fulton Iron Works, with which his name has been associated ever since. Under his management the Fulton Iron Works grew in prosperity. Two fires, however, proved disastrous, and about ten years ago Mr. Spiers, president and general manager, established the foundry at Harbor View. As a ship-building and engineering establishment, ranking with the larg-

est on the coast, the Fulton Iron Works stand largely as a monument to the energy and zeal of Mr. Spiers. But the strenuousness of his life proving too great, three years ago a stroke of apoplexy put an end to his active career and on the thirteenth of August, 1902, at the age of sixty-six, his strong constitution finally succumbed. Though a member of many societies and clubs Mr. Spiers was chiefly interested in educational matters. Having lead in Edinburgh free classes in mechanical drawing for young men, he took a deep interest in the establishment of similar classes and work here, being a trustee of the Mechanics Institute for eighteen years and a trustee of the California School of Mechanical Arts, founded by James Lick, in which latter capacity he found an opportunity for his most effective activity. With a marked taste for literature and fine arts he always held Burns as his favorite author and flowers his greatest delight. His mechanical library was large and his knowledge of mechanics intricate and exact. He had a fine nature marked by justice and liberality. Arriving in San Francisco, with but small means, his fortune and his place in the community he gained wholly by his own effort.

It is ordered that a copy of these resolutions be sent to the family of our late fellow-member, and that they be also spread upon the records of the Society.

Otto von Geldern, *Committee.*

Oscar F. Whitford.

Member of the Engineers' Society of Western New York.

Oscar F. Whitford, third child and second son of Earl Hartwell, and Asenath (Palmer) Whitford, was born July 15, 1833, in the town of Northumberland, Saratoga county, N. Y. Died May 21, 1902.

He lived on his father's farm where he was born until he grew to manhood, attending District Schools, Schuyerville Academy and a preparatory school at Charlotteville, N. Y. After graduating from Union College in the classical course in 1858, having taken a part of the engineering course as extra under Professor Gillispie, he went to Mississippi where he taught school and sold machinery until 1861, when he returned to Union College to take a post-graduate course in chemistry, receiving the degree of A.M. In 1862 he was a volunteer in the U. S. Army for four months to escort and protect emigrants across the Western Plains and Rocky

Mountains. After this service he engaged in gold mining enterprises in California and Idaho for about a year, leaving this work to accept the chair of mathematics and civil engineering in the Peoples' College, at Havana, N. Y. (now Montour Falls). For a period of ten years up to 1876 he was employed on New York state canals in the Engineering Department in charge of work first on the Chenango canal and afterward on the Erie canal. Leaving this service he engaged in lead mining in Missouri for two years, after which he was engineer on construction of the Southern Kansas Railroad for a year. The following year, 1880, was taken up in testing cements and the duties of general storekeeper for the Plattsmouth bridge. Silver and gold mining occupied his attention in Colorado and Mexico from 1881 to 1887; the last two years of this period as superintendent of the Santa Barbara mines at Chihuahua.

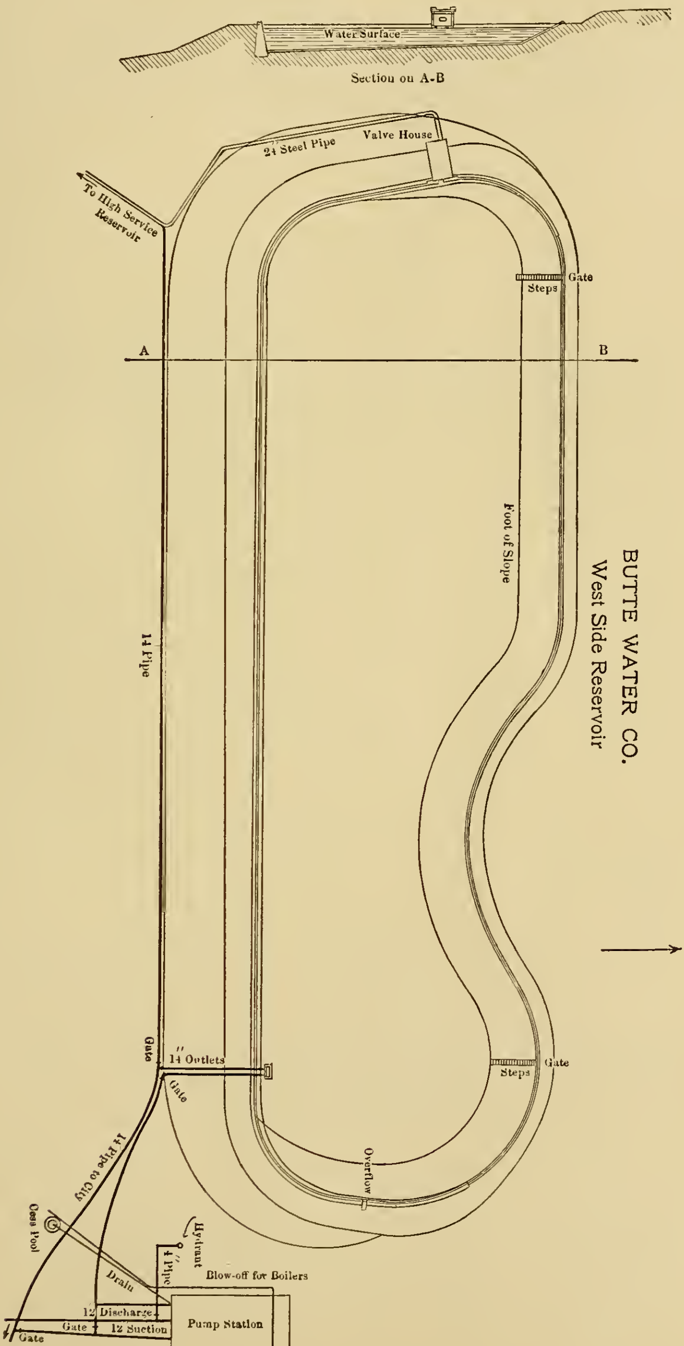
From 1888 to 1890 he was employed as engineer for contractors on railroads being constructed for the Chilean government.

Returning to the United States he was engaged as assistant engineer on the Michigan Central Railroad; then as general inspector in the Bureau of Engineering of the city of Buffalo up to 1898. Since that time and up to his death he was occupied with varied engineering enterprises. He was a man of kind disposition, remarkably even temperament, loyal to his friends, kind and considerate to his subordinates. He was unmarried. He is survived by two brothers and one sister, David E. Whitford, of Syracuse, N. Y.; Hiram P. Whitford, and Mrs. Mary E. Rugg, of Saratoga Springs, N. Y.

Mr. Whitford was elected a member of the American Society of Civil Engineers, December 6, 1871. He was a charter member of the Engineers' Society of Western New York.

Samuel J. Fields, *Committee,*
Engineers' Society of Western New York.

To accompany paper on "The New Works and Water Supply of the Butte Water Company," by Charles W. Paine, published in the JOURNAL for October, 1902, Vol. XXIX, No. 4.



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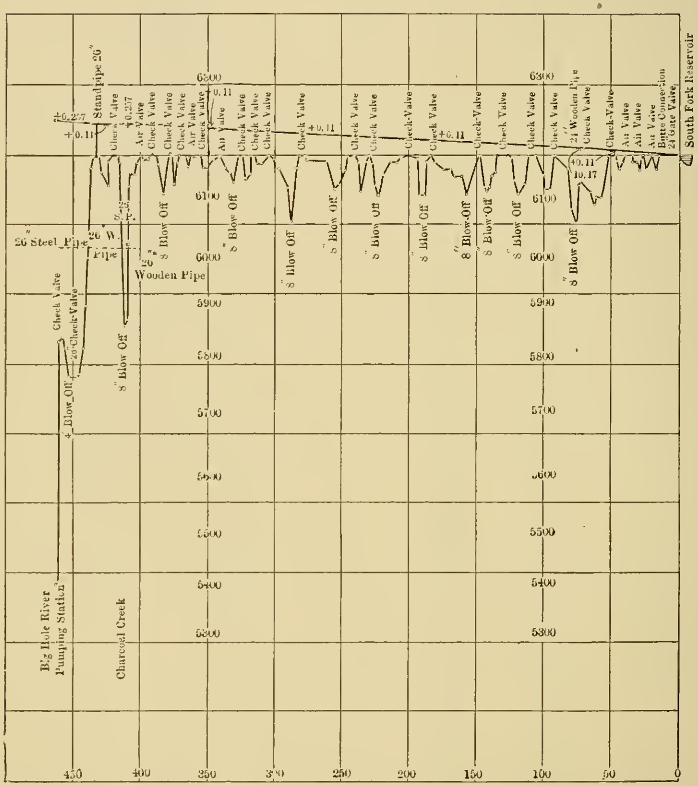
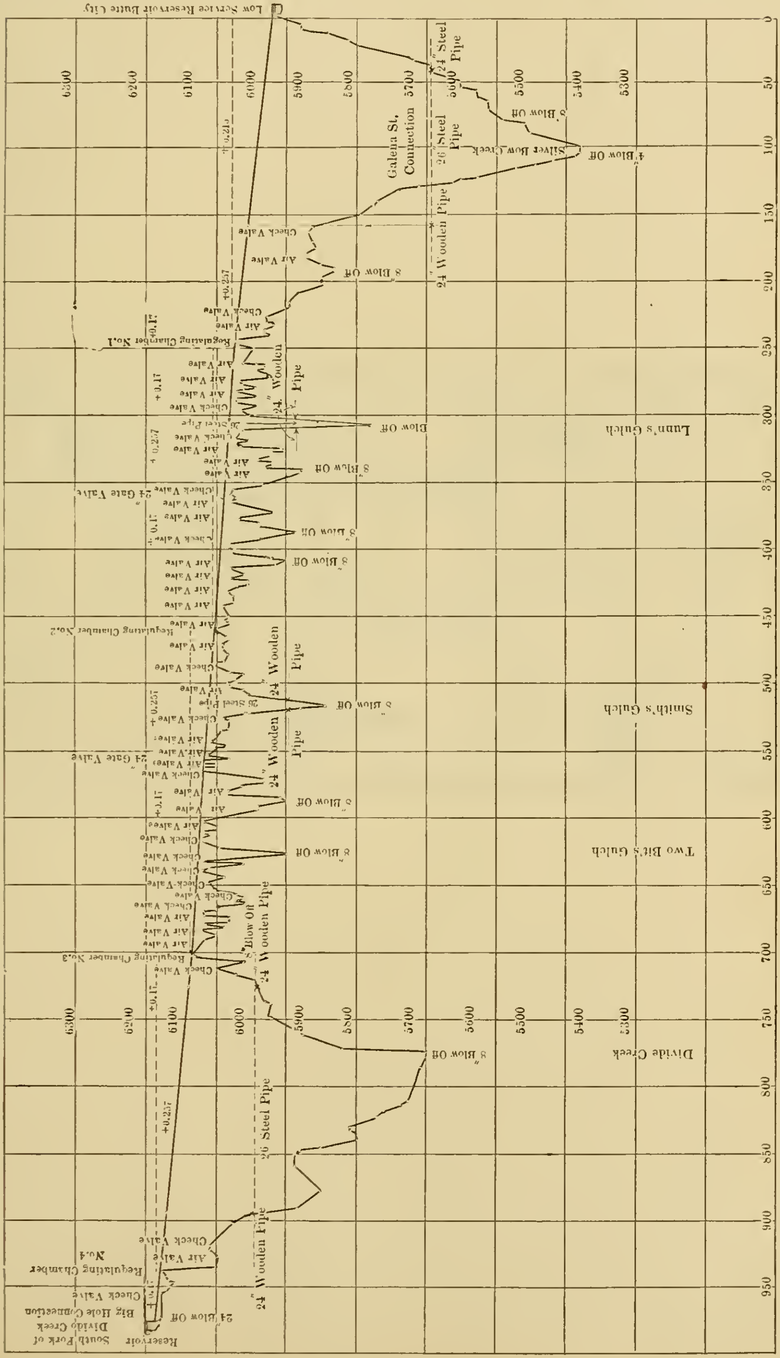
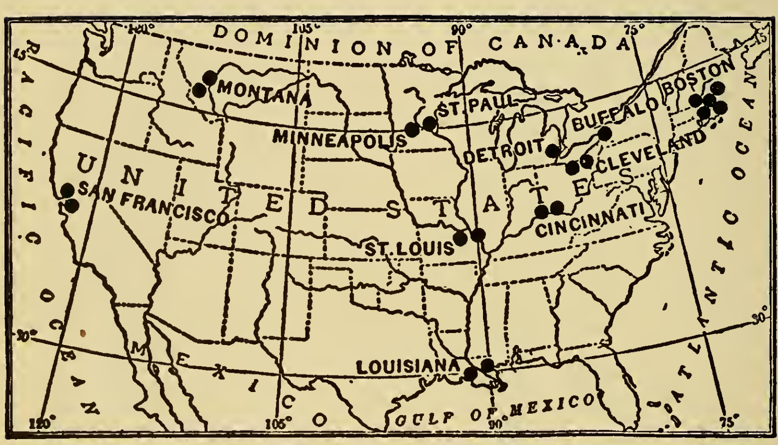


CONDENSED PROFILE OF BIG HOLE EXTENSION FROM SOUTH FORK RESERVOIR TO BIG HOLE PUMPING STATION.

To accompany paper on "The New Works and Water Supply of the Butte Water Company," by Charles W. Paine, published in the JOURNAL for October, 1902, Vol. XXIX, No. 4.



CONDENSED PROFILE OF BIG HOLE PIPE LINE FROM LOW SERVICE RESERVOIR, BUTTE, TO SOUTH FORK RESERVOIR.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BUFFALO
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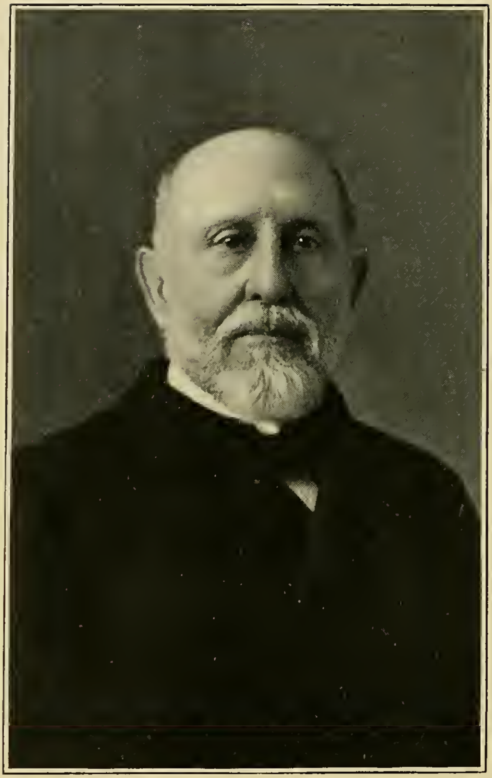

COLONEL G. H. MENDELL.

One of the Founders, and First President, of the Technical Society of the Pacific Coast.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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Organized 1881.

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

TUNNEL CONSTRUCTION UNDER WATER.

By Howard A. Carson, Member Boston Society of Civil Engineers.

[Abstract of informal remarks made at the meeting of the Society, September 17, 1902.*]

In the East Boston Tunnel the advance excavation consists of two side-wall drifts, Fig. 1, which are solidly timbered and are kept from 60 to 150 feet ahead of the shield, so that the walls built in them will be at least 10 days old when the shield reaches them. These side walls are built to a height about 16 inches below the springing line of the arch, Fig. 2. The shield, Fig. 3, resting on rollers, passes along on these side walls, and the main excavation is done under the shield. The sixteen rings shown in Fig. 3, omitting the two central ones, illustrate the positions of the hydraulic jacks which push the shield. These react against cast-iron rods, Figs. 4 and 7, which are continuously imbedded in the concrete of the arch. The arch is built under the tail end of the shield and joins the side walls, and the bottom of the invert is put in later, so that the masonry is continuous all the way around. Steel ribs, Fig. 5, 2½ feet apart support 4-inch lagging, and on that the concrete arch is turned. Fig. 6 shows the positions of the three air-locks. Figs. 3 and 5 show the rear end of the shield and the cross pieces which serve not only to strengthen the shield, but as a platform on which the operations of building the arch are carried on. Figs. 5 and 7 show the plungers of the jacks. Each plunger, Fig. 7, has at its end a wooden bulkhead about 2½ feet high by about 3 feet wide. These make a continuous dam all around the arch and prevent the fresh concrete from flowing over toward the shield. At present the air

*The regular paper which had been provided for the evening was postponed on account of the absence of some who wished to participate in the discussion and Mr. Carson was called upon in consequence.

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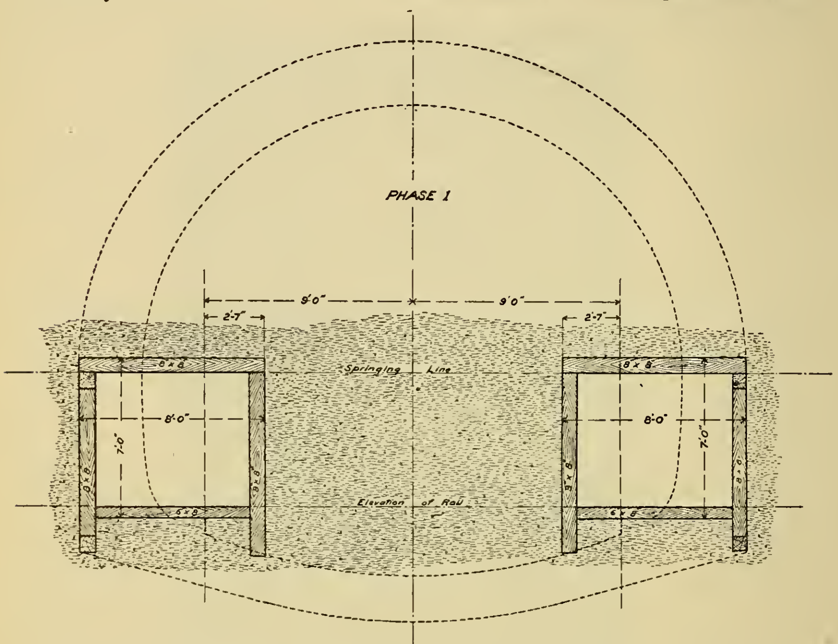
pressure in advance of the air-locks is about 23 pounds above the atmosphere, and it has never been above 25. The two lower air-locks are used for passing out the excavated earth and for carrying in the concrete. The upper one is entirely for persons, and would serve as an emergency air-lock in case the lower part of the tunnel should become filled with water. The shield system employed in constructing the East Boston Tunnel is essentially the same as that employed in constructing the tunnel portion of the Boston Subway, in Tremont Street, the main differences being that in the



CROSS SECTION SHOWING SIDE DRIFTS
EAST BOSTON TUNNEL

Fig. 1.

Tremont Street tunnel the arch was of brickwork instead of concrete, and compressed air was not used. The East Boston shield is taller and stronger than that of Tremont Street, and has more jacks.

In Paris, for the Metropolitan Subway, built in 1898-99, the width of the shields was a little less than those of the East Boston Tunnel, and their height was also less. For the Paris shields the jacks, instead of being placed near the outer skin of the shield, were nearer the axis, and, instead of pushing against iron rods,

buried in the concrete and thus wasted, they reacted against longitudinal braces which were fastened to the centering. By having enough of these braces, and by having the farthest one rigidly connected to the masonry already in, the Paris subway builders were able to take them out from time to time and use them over again. The Parisian method does not secure so stiff a structure for the Jacks to react against, but in most or all of the Paris tunnels for the Metropolitan Subway the work was very near the surface of the ground, and, consequently, the weight

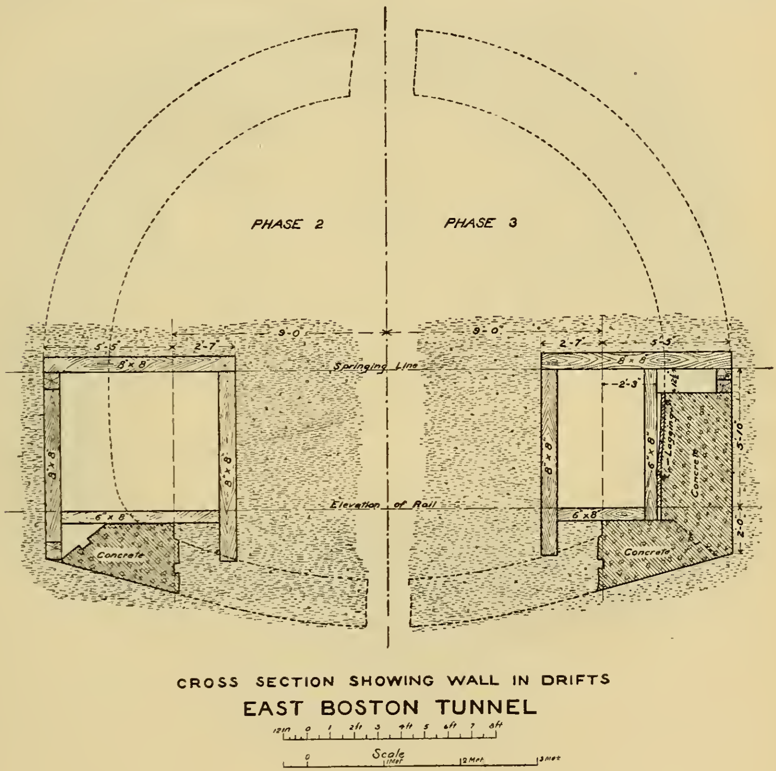


FIG. 2.

on the shield was light. A very interesting feature about a good deal of the Paris Work is that they turned the upper arch first, while in Boston the side walls are built first and the shield runs on them. In Paris the shields were run on a track composed of stout oak timbers and steel tracks, and the walls underneath were put in by underpinning. In the center a drift was made and kept a little in advance of the shield. This allowed them to take the earth directly from the face of the shield. The masonry of the Paris work is mainly composed of small stones, ranging in size from that

of a watermelon to that of a man's fist, laid in cement mortar. Some little of the structure was made of concrete blocks, which were molded out beforehand like cut stone. An experiment at making concrete in connection with the shield by a patented process did not succeed when first attempted. It may have succeeded since.

The East Boston Tunnel is between 23 and 24 feet wide inside; the arch and sides are 30 inches thick, and the invert, generally, 2 feet. It occasionally happens, however, that the shield departs from the line or grade, but the bore of the tunnel is always kept true. In

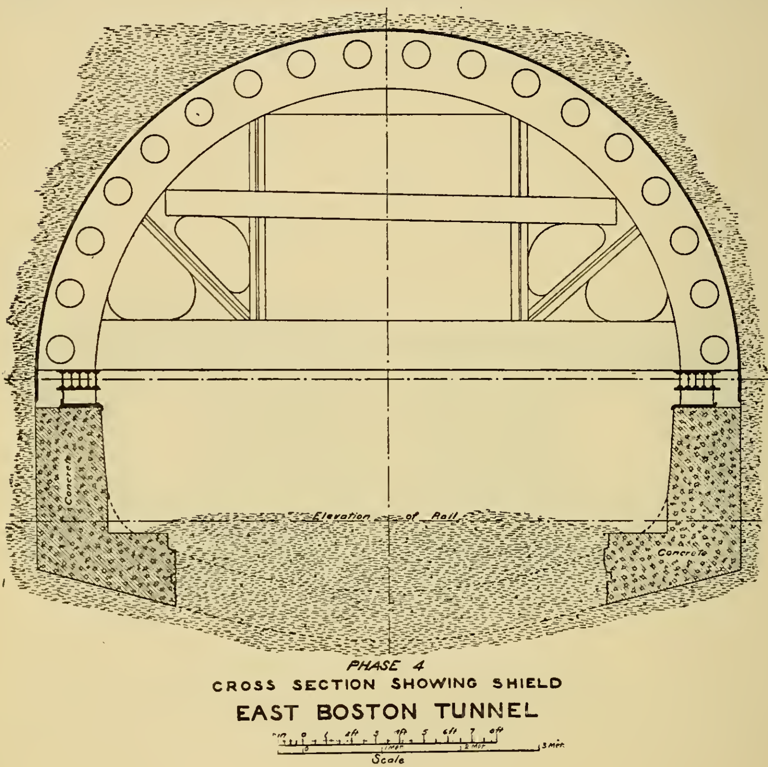


FIG. 3.

these cases the wall is of less than the normal thickness on one side, and of greater than normal thickness on the other. In one instance the shield got 6 inches out of line. There are 18 feet and upward of earth between the bottom of the harbor and the top of the tunnel, but when the harbor shall have been dredged to the 40-foot level there will be only 5 feet at the Harbor Commissioner's Lines. The depth of water is 35 feet at low water, and 10 feet more at high water, and at high-water the distance from the surface of the water to the bottom of the tunnel is about 88 feet.

Fig. 8 gives the relative sizes of a number of well-known tunnels made by the shield process. Among these were the City and South London, with twin tubes, each 10 feet 3 inches in diameter and part of the way 10 feet 6 inches; the Glasgow Cableway, a trifle larger; the Central London Railway, with an inside diameter of 11 feet 6 inches, opened a year or two ago, and the Waterloo and City, with an inside diameter of 12 feet 1¾ inches; the tunnel under the St. Clair River, and the Hudson River Tunnel. The latter was begun in 1880 and was finally abandoned in 1892, when one tube

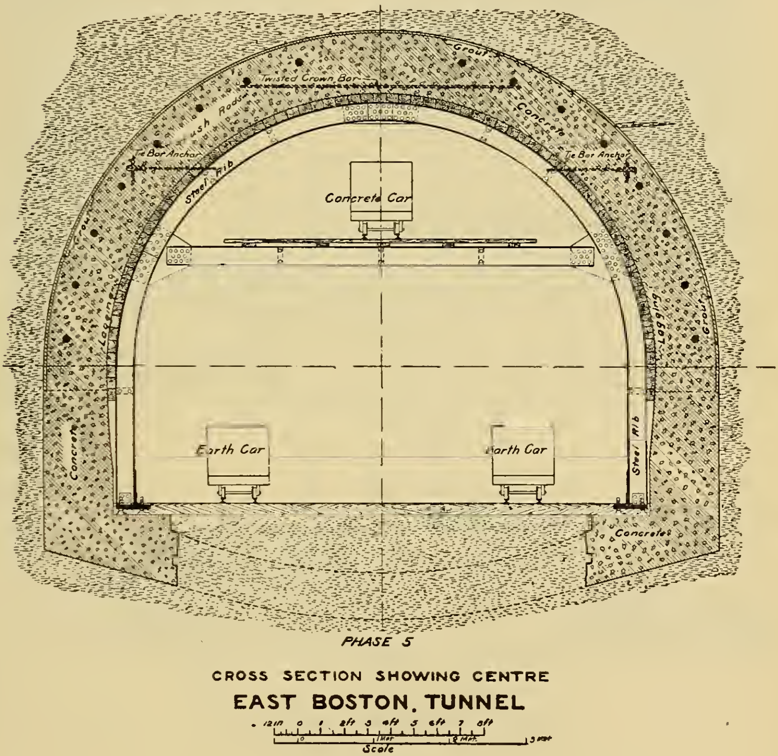
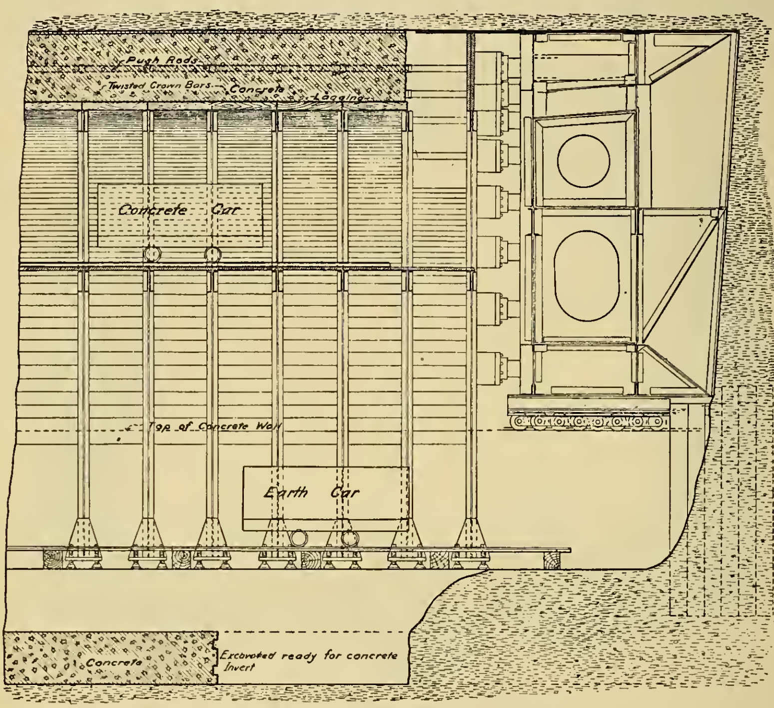


Fig. 4.

had been built about three-quarters of the way across the river. It is said that a company has been formed to complete the tunnel and use it for a trolley road. It has been pumped out, and when the speaker visited the tunnel, about a year ago, to see how the salt water had affected the cement, the latter appeared to be in excellent condition.

The East Boston Tunnel is about 2 feet wider on the outside than the Blackwall Tunnel, and about a foot narrower on the inside. The Blackwall Tunnel passes under the Thames for about 1200

feet. The East Boston Tunnel lies under Boston harbor, from the East Boston side of the South Ferry to Atlantic Avenue, which is a distance of about 3500 feet, or, taking it to the end of Long Wharf, something like 2800 feet. The total length of the Blackwall Tunnel built by one shield was 3100 feet, while on the East Boston Tunnel it will be in the neighborhood of 4400 feet. For about 400 feet the Blackwall Tunnel passed through gravel, or "ballast," to use the English term, which communicated directly with the water,



LONGITUDINAL SECTION AT SHIELD
EAST BOSTON TUNNEL

Scale

FIG. 5.

and formed the hardest job of tunneling under water of which the speaker was acquainted. The rest of the way was in very good material; some of it in clay very much like that found so generally in the East Boston Tunnel excavation. Some of the Blackwall Tunnel was driven through quicksand, which proved admirable material to work in under compressed air. While passing through the sand the Blackwall shield averaged a little over 8 feet per day for a number of months, and on one or two days the progress reached was

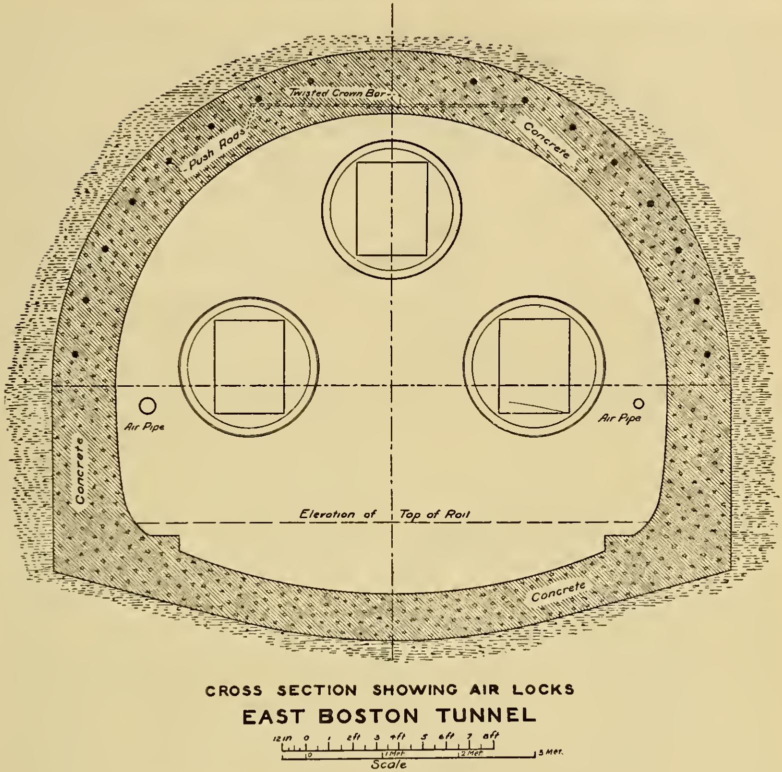


FIG. 6.

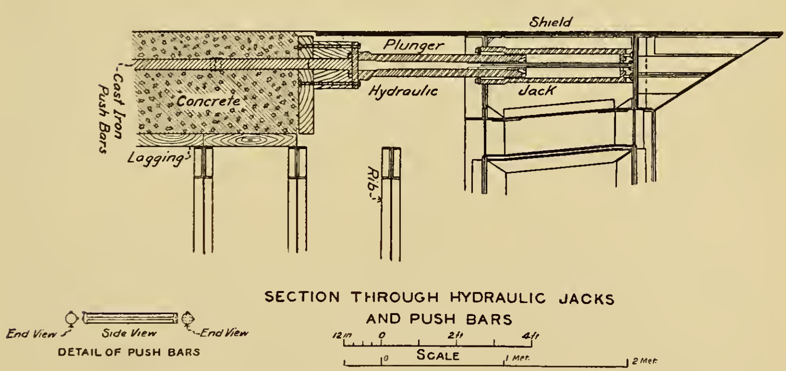


FIG. 7. SECTION B, EAST BOSTON TUNNEL.

12 feet 6 inches. In clay the shield progressed about 4 feet per day. From the time the Blackwall shield started until it ceased to be used the progress averaged 3 feet per day. The East Boston Tunnel progress was as follows: For the first 6 months in clay, taking the whole time, an average of 3 feet per day; the next 6 months

over 4 feet per day, and for the next something over 5 feet per day. This latter or a greater rate of progress will very likely be maintained to the end if no misfortune occurs, and this will bring the tunnel to Atlantic Avenue before October, 1903.

It seemed a pity that Colonel Haskin, who started the Hudson River Tunnel, worked so hard on it and who spent his own money and other people's on it, could not have lived to see it completed. It was probably his use of compressed air there which led to its use in horizontal tunneling all over the world. When the accident occurred on the Hudson River Tunnel, involving the loss of 21 lives, Sir John Fowler said the scheme of working by compressed air was a faulty one and would not work. Nevertheless, the use of compressed air has changed the whole history of tunneling since that time.

Two or three years ago, when the construction of the East Boston Tunnel was first discussed, and before it was actually decided to build it, consideration was given to the plan of excavating a trench and putting in two tubes from the top. It was originally intended to have the tunnel near the bed of the harbor and to have two tubes, each for a single track, instead of having a deep tunnel with a single tube wide enough for two tracks. Each of the permits given from time to time by the Secretary of War contained a provision that, if the War Department at any time wished to deepen the harbor, the tunnel must be moved, if in the way, and, consequently, in each new scheme the tunnel was planned to be a little deeper. Finally the Transit Commissioners decided they did not want two tubes, although they would have been somewhat cheaper than one, and would have given better grades. The Commissioners thought that the public would prefer a tunnel wide enough for two tracks. The proposed twin single tunnels were to be each 16 feet wide inside and 18 or 19 feet wide outside. As it is now, the surface of the harbor is about 90 feet above the bottom of the masonry. In case a channel had been dredged, it would have been part of the way through hard-pan or clay containing bowlders, and the amount of excavation per running foot would have been at least 120 cubic yards. Mr. Perkins, of the contracting firm of Perkins & White, thought he could do dredging under these conditions for $1 per yard. This price would amount to the same that it has cost per running foot for excavation with the shield. If we assume that in some manner concrete tubes could have been made, lowered and connected as cheaply as the tube is

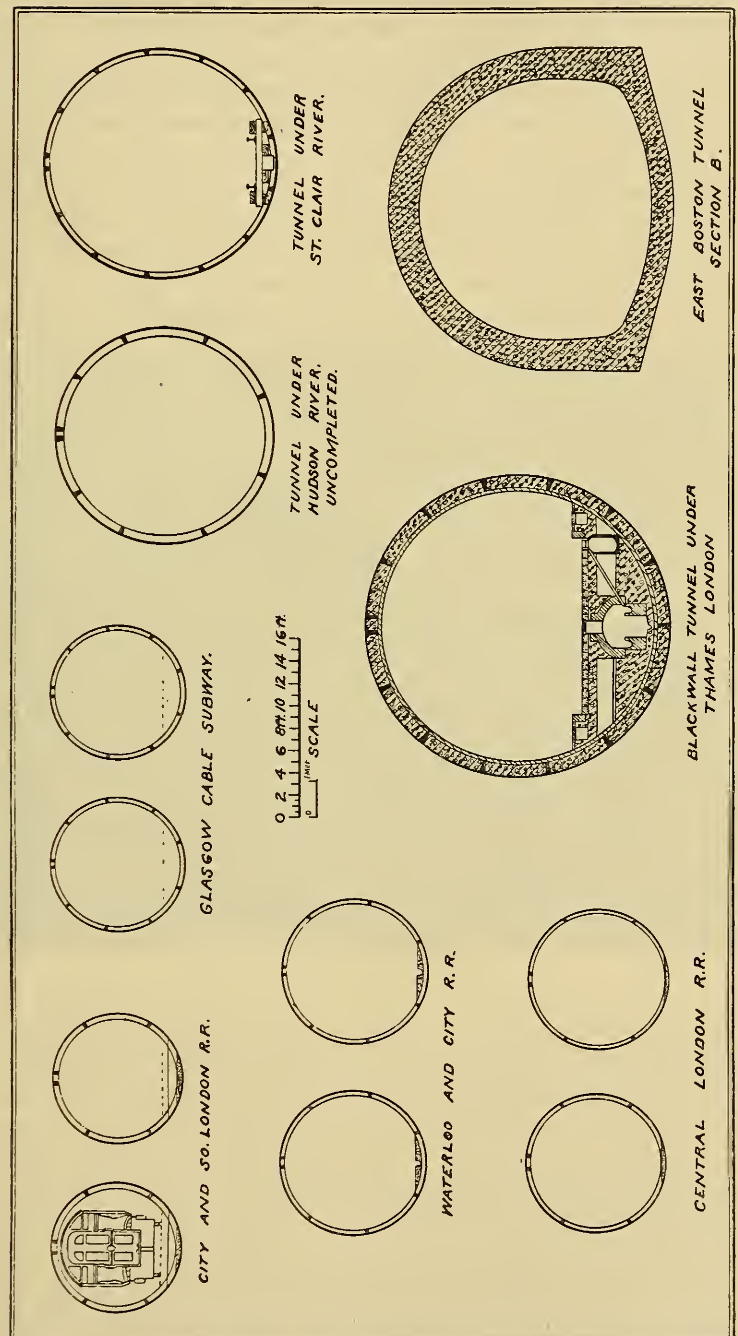


Fig. 8. Relative Sizes of Various Tunnels.

built by the tunnel process, the cost would be exactly the same as at present, but there might have been a great saving in time.

Zera Colburn, an American and a genius, who went over to London and founded the very successful paper called *Engineering*, had a scheme for a tunnel across the English channel, briefly outlined as follows:

"The tube would be floated, not certainly upon the surface, but by means of buoys just clear of the bottom, the tube being again grounded as soon as it had advanced a length. . . . . The seaward end of the tube (of great strength) would, of course, be closed, and it would be provided with suitable fittings for attaching the powerful hauling-out tackle to be used when the successive lengths were floated. The dock gates would close around the tube so as to form a water-tight joint. The tube would be of such dimensions and thickness that, previous to putting in the brick lining, its own weight would be as nearly as possible exactly the same as that of the sea water displaced, so that of itself it would, so to speak, neither sink nor swim. . . . . When a length had been completed and the tube was ready for launching, its inshore end would be closed water-tight, the buoys made fast in place, the dock gates opened and the sea admitted. The tube would then be drawn up well clear of the bottom by means of the adjustable

FIG. 9.

tackle connected with the buoys, and the whole of the tube of whatever number of connected lengths of 1000 feet would be drawn out to sea for a distance corresponding to the length last added."

Another scheme was that of General Foster, who was then (1870) United States Engineer Officer at Boston. He proposed sections of tube, closed by bulkheads. The sections were to be lowered into a dredged trench and then joined by divers, and were to have suitable packing between the segments. The General did not state how the divers were to proceed, nor of what the packing was to consist.

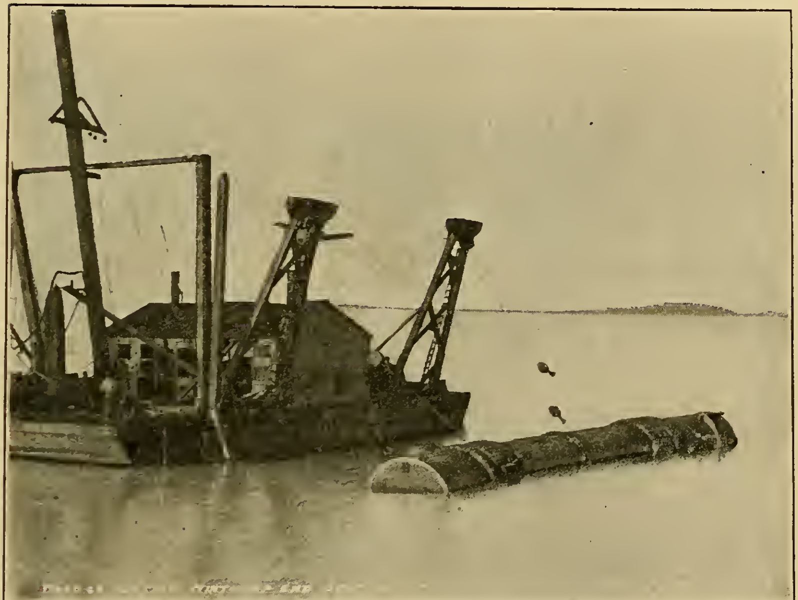


FIG. 10.

In the scheme of Martin and Le Gay, two French engineers, for a tunnel across the English Channel, the sections of the tunnel were to be floated into position between two cables running longitudinally, and were to be lowered by other cables, and the joints were to be made by dumping concrete through the water over the contiguous ends of the pipes.

Figs. 9, 10 and 11 illustrate the method of laying the syphon under Shirley Gut, and the outfall of the sewerage system at the outer end of Deer Island. The Shirley Gut pipes were from 50 to 65 feet long, made of iron and brick, their external diameter being between 9 and 10 feet. They had tight bulkheads at each end. They were moved down to low water with blocking and rollers, as a house is moved. At high water they were dragged off from

their blocking and floated over the place they were to occupy, enough water was let in to sink them, and they were accurately placed on the bottom and then bolted together by divers. The sections for the Deer Island outfall were made of concentric rings of concrete and brickwork, with wooden staves outside to protect the masonry from blows and abrasion. These sections were made in cradles which were placed side of a wharf and above water, and each section or pipe weighed about 220,000 pounds. They were lowered into water by screw bolts, by means of a suitable engine, and were then towed out half a mile or so to their proper position, sunk on accurately-placed saddles and connected by divers. The joints be-

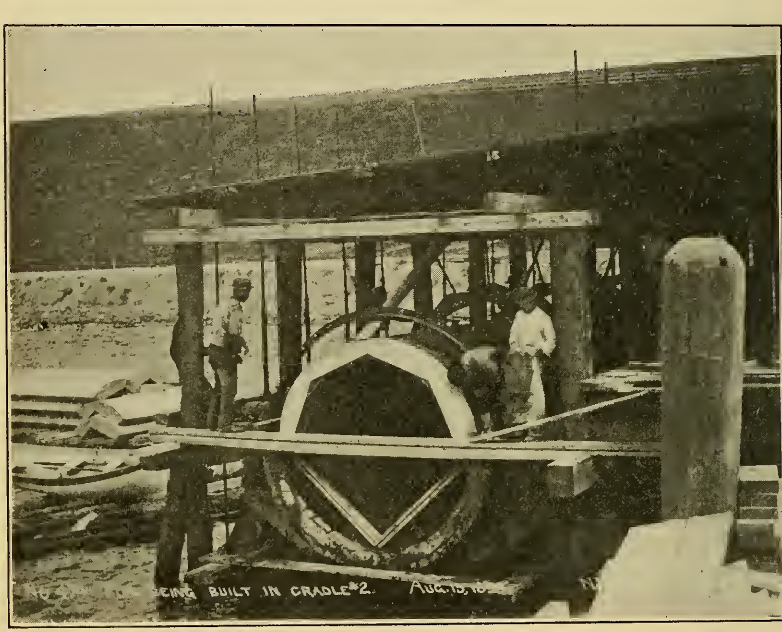


Fig. 11.

tween consecutive pipes, both at Shirley Gut and at the outfall, were made tight by rubber gaskets. The bulkheads were removed at a later time and the brickwork was made continuous.

The Harlem River pipes of the New York rapid transit system are to have an internal diameter of 16 feet, and are to be made of cast-iron surrounded by concrete. The river is about 400 feet wide at the point where this construction is being put in. A description of this work has been furnished by Mr. George S. Rice, a member of the Boston Society of Civil Engineers and Deputy Chief Engineer of the New York Rapid Transit Commission.*

*Mr. Rice's paper appears in the following discussion.—Secretary, Ass'n of Eng. Socs.

DISCUSSION.

John F. O'Rourke, of New York, Director of the American Society of Civil Engineers.—The method about to be described can hardly be called tunneling, but when the work is finished the result is a tunnel. There are conditions where a tunnel, if driven, will be either too far down or in material which is not secure and reliable. Nearly all tunnels are too low, and the author believes that following the designs he is about to explain will result in a tunnel which will be permanent when completed. He would suggest placing a tunnel as near the surface of the water as the harbor conditions will permit. The bed of the Harlem River is 27 feet below low water. The regulation for a tunnel there is that it shall be kept 45 feet below low water, providing the tunnel is put in from the surface. By the methods about to be described the tunnel could be put through there, in soil which is not very secure. The author has two methods for placing tunnels from the surface down and providing absolutely secure foundations for them. One method is to build the tunnel under water, completing the tunnel as a submarine operation, without any interference with the water or removal of water until the tunnel is completed. This is an ideal way when only ordinary depths and ordinary currents are to be encountered. Where the conditions as to depth and currents are less favorable, and where the bottom is insecure, the second method should be followed. Both methods of doing the work are by a combination of different operations that are well known and easily accomplished, so it is not attempting anything new in the operations themselves, but getting new results from old methods. The first thing to know is that you can place concrete under water so that the concrete will be as good as if placed in air. This has been accomplished. Three or four years ago the author was building the City Island bridge, and he had very difficult foundations to place. It was impossible, especially with the amount of money available, to do the work except by placing the concrete through water. In a sanguine moment the speaker promised to get up a concrete box which would not admit of spilling out the concrete before it got to the bottom. Fig. 1 illustrates the bucket designed and patented for this purpose. On the City Island job there were only three cases of failure to place the concrete properly with these buckets. On this job the concrete was stopped within 12 feet of high-water level. After the concrete had been allowed to set for a few days, the water was pumped out of the structure, and the concrete as found to be actually as hard as if placed in the air. There were slight irregularities on top, but the concrete was perfectly hard and sound.

There was absolutely no leak of water. That is an object-lesson to the effect that concrete can be successfully placed under water.

Fig. 2 illustrates the first method mentioned. The various steps are (Section No. 1) dredging a ditch in the bed of a body of water for a given length of 200 or 300 feet, and driving piling for foundation (Section No. 2), driving sheet piling lengthwise

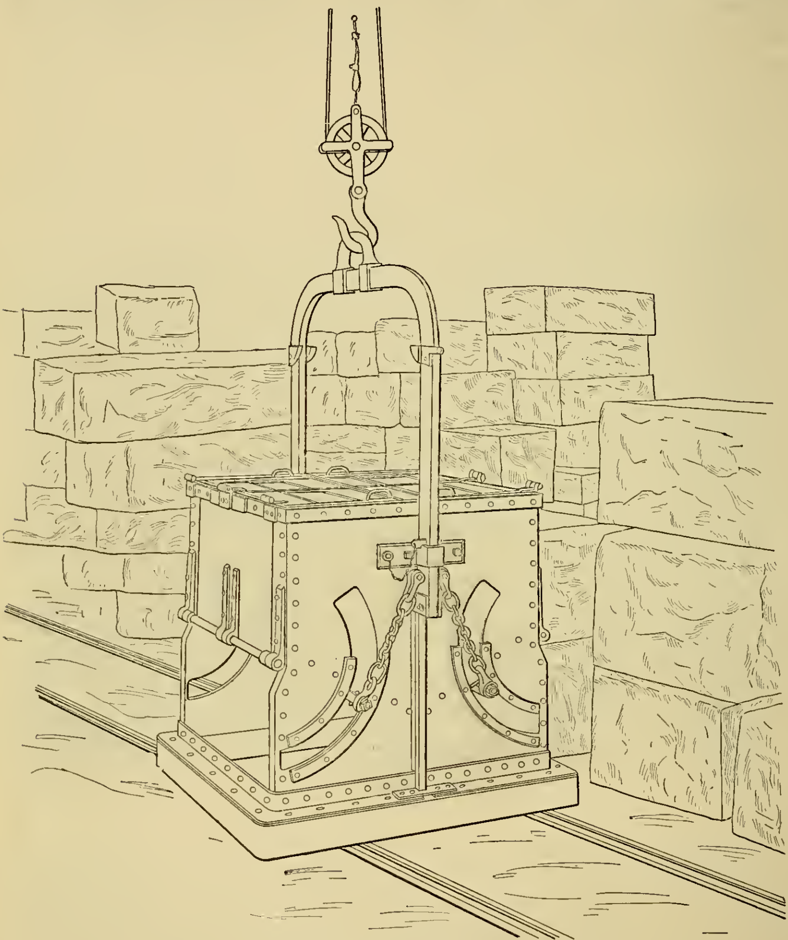


FIG. 1. BUCKET FOR DEPOSITING CONCRETE.

of the ditch to form a mold and cut off the current, and placing through the water a bed of concrete of a thickness to correspond with the bottom of the tunnel, say 5 or 6 feet. Then divers may be sent down to smooth off the tunnel invert or a machine may be made for this cleaning off, but it is not very much of a trick for a diver to go down with a shovel and pick and do the leveling.

The next operation (Section No. 3) is to get a center in place. The center is built on the surface, on platforms on each side, so that it can be held properly. The center is lowered onto the concrete invert already in place. There are various methods of making the centering. A bulkhead is made at the advanced end of the trench, but the water all the time remains inside. Concrete to form the roof and sides is placed through the water (Section No. 4), and thus one section of the tunnel is made (Section No. 5). For the next step the operations are repeated. The floor is kept a little in advance, so that sections break joints, and thus, step by step, and breaking joints as we go, the tunnel is built. After the tunnel is finished it is pumped out and any leaks are stopped. By following this plan pumping is avoided until there are concrete walls on all sides.

In the method just described it is necessary to have sheet piling extending down 100 feet from the surface. In the Hudson River this would be impossible, because of the two or three different kinds of current existing at different levels and their great strength. The current will be running up in the top and middle and down at the bottom and sides, according to the stage of the tide. This was the case at Poughkeepsie, where the conditions are much the same as near New York.

The idea in this second scheme is to have something more or less complete before we attempt to put it in. A man describing himself as a newspaper man and an engineer, and as uniting in himself the facile power of description of the trained writer with the practical ideas of a thorough engineer, called upon the author and proposed to build a tunnel 3000 feet long on shore, slide it into the water and float it into position. Anyone, however, who thinks he can hold under control a structure like this in the river at this point with nothing but anchors will be disappointed. The way is not to make one long jump of it, but to get successive footholds, and these footholds are cribs. (See Figs. 3 to 8.) Cribs are simple matters to build, and they have been built in all kinds of rivers. Even if the cribs are not exactly in line or at the exact depth, it makes no practical difference, for the tunnel may nevertheless be placed where it should be. In a general way, the distance between the crib centers is about 800 feet. This distance is not difficult to deal with, except on account of the short time available for placing the tunnel spans between tides, say about half and hour. The cribs or caissons are constructed and are placed in position at distances apart corresponding to the lengths of the tunnel sections, and the sections themselves are then placed in position (with the ends sup-

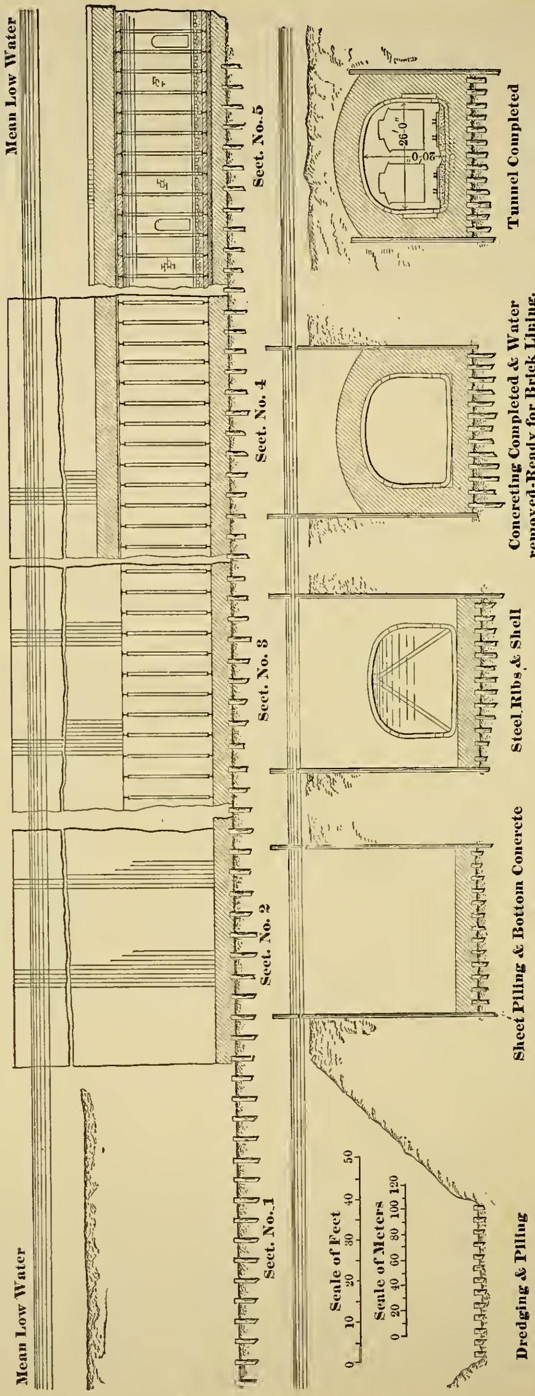
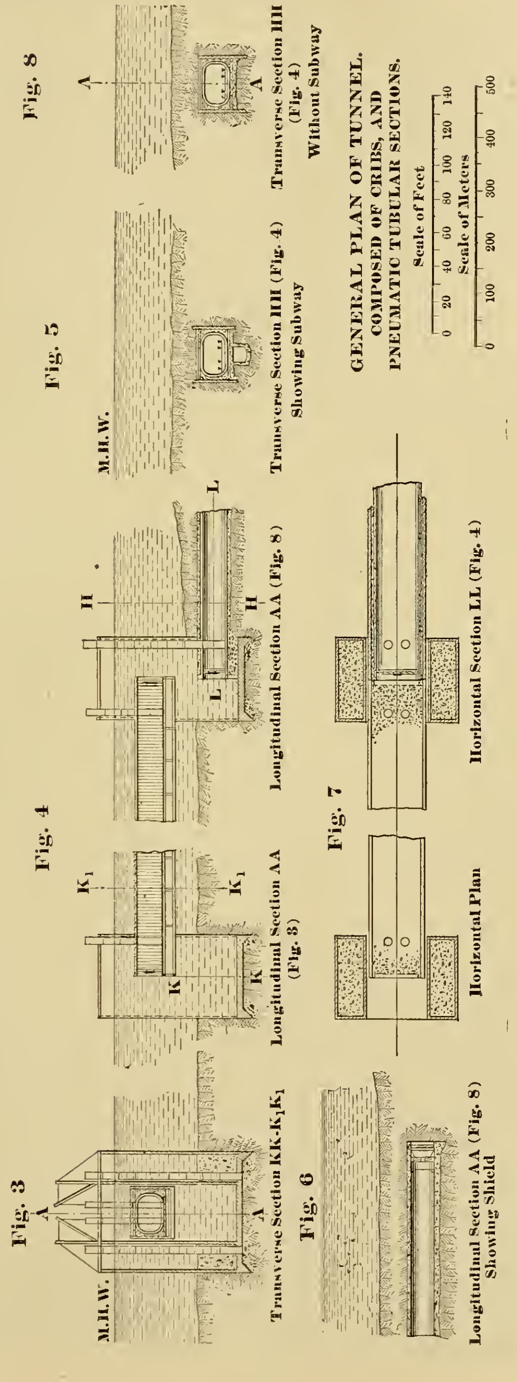


Fig. 2. GENERAL PLAN OF TUNNEL, CONSTRUCTED OF CONCRETE PLACED UNDER WATER.



GENERAL PLAN OF TUNNEL. COMPOSED OF CRIBS, AND PNEUMATIC TUBULAR SECTIONS.

ported on cribs), the connection of two adjoining sections being effected within the crib. Each tunnel section, which may be built ashore or afloat, as may be most convenient under the circumstances, comprises a steel tube of suitable form and a sustaining vessel therefor, which may be constructed of any desired material or shape. The vessel, with the tube therein, may be ballasted by placing concrete (which forms a part of the permanent structure) between the tube and the vertical walls of the vessel; and, when it has been brought to the desired position, it is sunk by adding more concrete or ballast to the vessel. The concrete at the ends of the tube is placed after the two sections of the tunnel are in place to form the joint, and near each end of the tubes one or more working shafts are carried from the top to give access to the space beneath the tube, such shafts being continued upward as the vessel and tube are sunk to place, so that the upper ends of the shafts are always above the surface of the water. A bulkhead is put in the end of each tube. While the tubes and their containing vessels are being sunk, they are guided to their proper line and grade by the shape of the openings made in the walls of the cribs. The cribs are strong enough to hold the tunnel sections against the tides during sinking. As the tunnel section sinks, a bulkhead may be carried upward at the top of the tunnel section between the walls of the crib, to exclude water currents from the interior of the crib; or, if conditions permit, such bulkhead may be placed after the tunnel section has reached its position of rest, if it be deemed necessary, so that concrete deposited through the water may be filled around the ends of the projecting tubes. When two adjoining tunnel sections have been thus placed, a temporary joint is made between the abutting ends of the steel tubes and the masonry is made continuous. When the tunnel sections have been placed and united, the upper portions of the cribs or caissons may be removed to the top of the tunnel sections. The cribs are perfectly constructed in a cellular manner, being divided by interior vertical walls to form chambers or pockets for the reception of the ballast necessary to sink the crib. The crib is also provided with a dredging chamber, through which the material excavated beneath the crib may be removed as the crib is sunk to position. A pneumatic caisson, however, may be employed when the conditions are such as to render its use desirable. If necessary, a bed for the tunnel sections is dredged in the bottom of the river prior to their being sunk.

This scheme might easily be applied in sinking the tunnels to be made by the Pennsylvania, New York and Long Island Railroad. There are plenty of places on the shore of the river for building

tunnel sections in 800-foot lengths, and they could then be run down into the water and towed out at a favorable time and put into place. All that is necessary is to get the railroad company to award the contract and furnish the necessary funds.

John Ericson, City Engineer of Chicago.—The question of subways to accommodate all surface and elevated street railway traffic in the congested business district is at present being agitated by the people of Chicago, and, as the general concensus of opinion favors their construction, it is safe to presume that such subways will be built, probably in the near future.

Three subways have so far been constructed under the Chicago River for the cable roads, sewer and water tunnels and conduits for telephone and telegraph wires. Of the water tunnels the writer has designed and supervised the construction of about twenty miles, varying in internal diameter from 5 to 10 feet. These conduits are generally about ninety feet below the surface, and run through glacial clay and gravel in the eastern half, and through Niagara limestone in the western half of the city. Of course, there have been difficulties in the construction of even these, especially as all tunnels run from two to four miles under Lake Michigan, where the bores encounter explosive gases, water, quicksand and friable clay which will not remain in place, but it was not, of course, so difficult as constructing the tunnels described by the preceding speakers, especially if the structure were under a bay of the ocean. Chicago is also now building an intercepting sewer system, which includes some large sewers, one being a tunnel 2¼ miles long and 20 feet internal diameter, which is being worked with hydraulic shields.

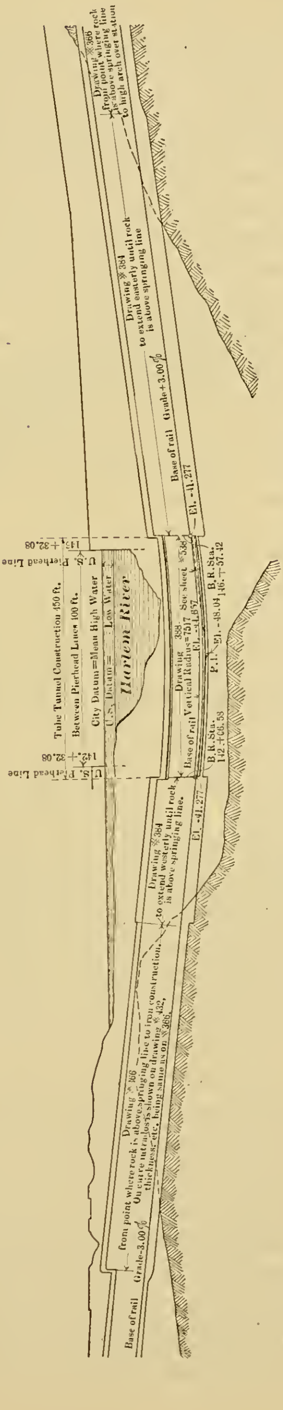
The Illinois Telephone and Telegraph Company, a private corporation, is constructing a system of conduits, which are worth mentioning on account of the skillful way in which they are made to progress and the little annoyance caused to the public, though said construction is in the heart of the most congested business quarter, for it is being built under practically every street in the down-town district. When this company was organized and undertook to arrange for a telephone system, it was found that the streets were so fully occupied by existing companies that space could hardly be found for a 6-inch tube, so permission was obtained to construct this system of tunnels. Basements were rented in large houses along the line of the proposed system and used entirely for the operations of construction. The shafts were sunk close to these basements, and headhouses of galvanized iron, tastefully painted, were erected over them. The spoil taken from the shafts was stored in the rented basements and hauled away at night, so that no material was taken

through the streets, except after 7 o'clock P.M. Later, the company built an incline at one of the shafts on the river. At this incline there was installed an endless conveying chain system, with dogs constructed in such a manner that they took hold of the axles of the tunnel cars and conveyed them to the ground surface, where the material was dumped into scows. At the edge of the river a system of moving platforms was erected, and these platforms were so constructed that they could be raised or lowered for loading the scows, and thus not interfere with boats going up or down the river when not in use. This method of handling excavated matter has been found to be very economical and expeditious. The crown of the arch of these tunnels is about 30 feet below the street surface, and in cross-section the conduits are of horseshoe shape, 7 feet 6 inches high by 6 feet wide. The walls and arch are 10 inches thick, floor 13 inches thick, and are made throughout the entire system of Portland cement concrete (generally a gravel concrete, proportions 1 to 6), and are practically impervious to water. Over 12 miles have been completed, and work is progressing rapidly, as it is intended to build many miles more, carrying the tunnels under the river into the residence districts of the north, west and south sides of the city. The writer had supervision of this work for the city, and any complaints on account of annoyance would have been made to him, but so far none have been made; in fact, the citizens of Chicago do not appear to be aware that any tunneling is going on, as all they see of the operations is, once in a while, a load of cement or gravel dumped into the basement of a house, and, after this has gone on day after day for a month or so, they begin to wonder how long it will take to complete the cement floor down in that cellar. Whether or not this conduit is to be used exclusively for telephone and telegraph purposes the writer does not know, as the company has applied for additional privileges, which have not been granted as yet.

MR. GEORGE S. RICE.—The following description of the work of constructing the tunnel under the Harlem River for the Rapid Transit Railroad Commissioners of the City of New York is furnished at the request of Mr. Wm. Barclay Parsons, the Chief Engineer of the work.

This two-track tunnel will be the means of connecting Manhattan Island with the Borough of the Bronx for the Rapid Transit Railway, and is now under construction by the contractors, who have devised the following-described method of doing this work.

Beginning at the west bank of the river and extending across it, along the line of the tunnel, a strip 50 feet wide at the bottom was



Scale, Horizontal, 1 = 4320
Vertical, 1 = 1080

FIG. 1. PROFILE OF HARLEM RIVER TUNNEL AND APPROACHES.

NOTES.—Rock line shown is approximate only.
Elevations shown are referred to city datum.
Sections given are on division engineer's survey.

excavated with a dredge to a depth of 39 feet at the center of the river, at which point it is about 10 feet above sub-grade. From this point the bottom of the dredged channel runs along parallel to the sub-grade until it reaches the rock surface at the west end. Substantial timber piers or platforms, supported by piles, were built on each side of the tunnel line, and waling strips were bolted to the sides of the piles at such a distance that they furnish a guide for the outside of the heavy 12-inch sheathing, which was afterwards driven to form the sides of the coffer dam. The maximum width, from inside to inside of this sheathing, is 33 feet. These platforms serve a double purpose, both as working platforms to carry derricks and materials of construction, and also as a means of steadying the sheathing and the timber frame-work which supports it, thereby enabling the contractor to build his coffer dam, both open and covered, true to line and grade. These platforms extend only to the middle of the river at present, thereby leaving half of the channel open to traffic.

Beginning at the west bank of the river, for a distance of 200 feet, it is proposed to conduct the construction work in an open trench extending above the high-water mark. This trench is sheathed, at the river end, with 12-inch sheathing, driven in sets of three 12 x 12-inch hard pine timber bolted together, and with strips forming a tongue on one side and a groove on the other. At the shore end the sheathing was not so heavy, being 6 inches thick. At its east end, where the sheathing is 12 inches thick, it is supported by eight rows of cross timbers, the lower timbers being 16 inches square, and diminishing as they come up, until the top row is composed of 16 x 8-inch timbers. These cross braces are horizontally 10 feet apart, and butt against 16 x 16-inch waling strips at the bottom and 6 x 12-inch strips at the top. At the end of this stretch, station 140 + 71, the open trench method is abandoned, and instead two rows of sheet piling, one on either side, are driven and sawed off under the water at about the level of the top of our tunnel. Over this is placed a wooden roof, the idea being, when this is constructed, to pump the water out of this box and construct the tunnel inside of it. The method of building this wooden box is as follows:

At station 142 + 06, the bulkhead is constructed $12\frac{1}{2}$ feet wide, and long enough to extend across the tunnel. All four sides are sheathed with 12 x 12-inch timbers, driven as described above, in sets of three. Bents of piles of four each, spaced 8 feet apart, were driven between stations 140 + 71 and 142 + 06. These piles were then sawed off at a point just below the bottom of the timber roof,

capped and braced by means of divers. The bracing for the sheathing, consisting of three tiers of braces, the bottom one 16 x 16 inches, the top one 12 x 12 inches, were put together with the necessary waling strips and appurtenances, floated into position over these nests of piles and sunk into position resting on longitudinal strips, which had already been bolted to the piles at the proper height. The waling strips for this bracing range from 16 x 16 inches to 12 x 12 inches, and the whole frame-work was very thoroughly tied together by diagonal braces. Work was now

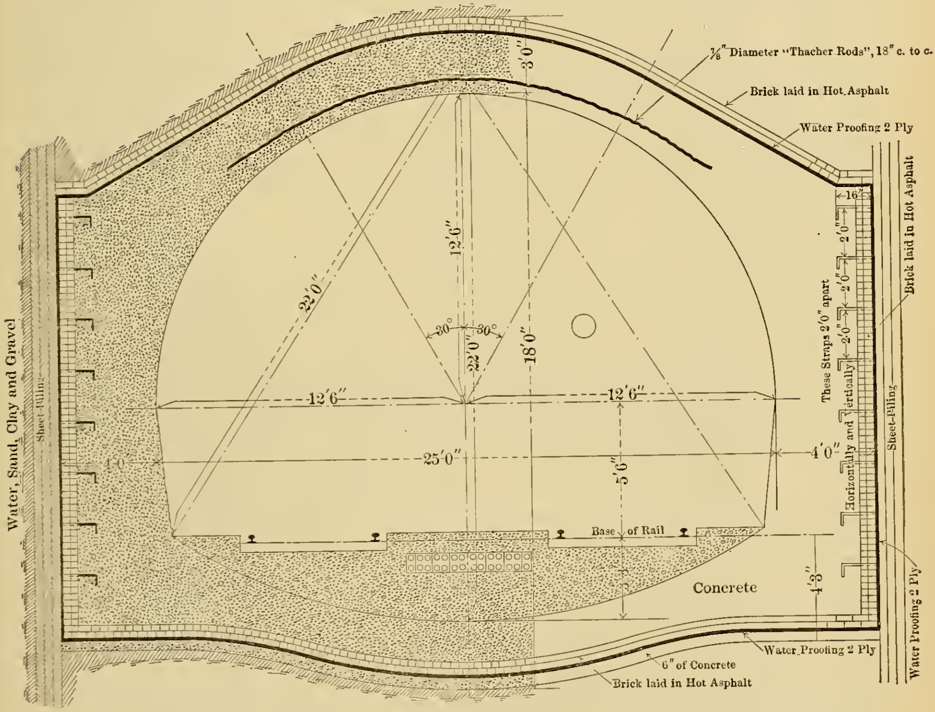


FIG. 2. TYPICAL SECTION OF CONCRETE ARCH, EAST APPROACH TO HARLEM RIVER TUNNEL.

Scale, 1 = 120.

begun, driving the 12-inch side sheathing. It was proposed to use a set of steel piles equipped with a water jet, to serve as guide piles, and break the ground preparatory to driving the timber sheathing. So far, it has not been found necessary to use these steel piles. The side sheathing having been driven into position, the next step was to saw off the same to the level of the bottom of the timber roof. This timber roof is 40 inches thick, consisting of three layers of 12 x 12-inch timbers, separated by two layers of 2-inch tongued and grooved planking, all securely spiked together. When this

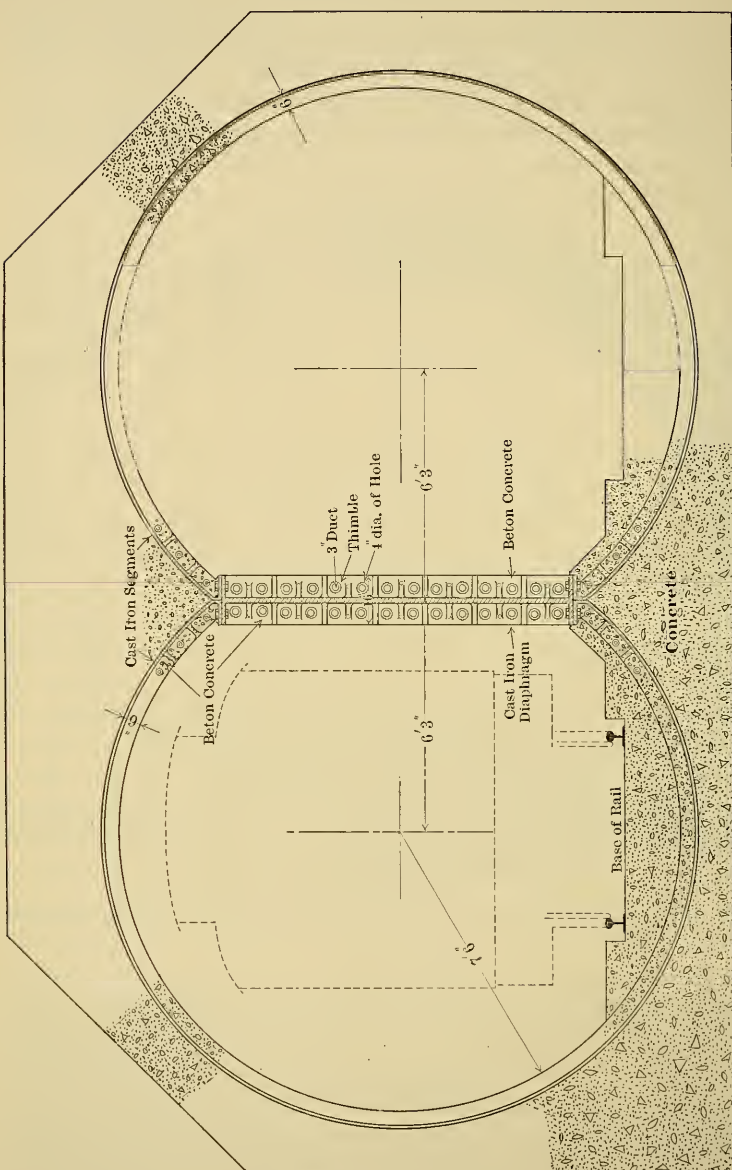


Fig. 3. Harlem River Tunnel. Transverse Section.

Scale, 1 = 60.

timber roof is in place and has been caulked, and when all joints have been caulked from the outside by the diver and the bulkhead at both ends of the strip is completed, the partition between the bulkhead and the box will be removed, and the water will be pumped out. The bottom will then be excavated to sub-grade, an additional row of braces put in and everything will be in readiness for the construction of the tunnel, the same as in open air.

The timber roof is to be weighted down, and earth is to be banked up on the outside of the sheathing, so that, if it is found necessary to prevent the clayey bottom from blowing, the contractors can put on air and prosecute the work as in a caisson. Through this stretch, as above described, the tunnel section is entirely of concrete. From the bulkhead at station 142 + 06, for a distance of 450 feet, which takes us to the other side of the river channel, the construction will consist of a double cast-iron tube, with a cast-iron diaphragm between, surrounded with concrete. The method of constructing the timber box, from the bulkhead at station 142 + 06 to the one at the centre of the river, a distance of 225 feet, is the same as described in the stretch which preceded, the only differences being in the height of the tunnel and in its width, which is considerably less. On the stretch from 140 + 71 to 142 + 06, it was found that the sheathing was so thoroughly toed into the clay below sub-grade that it has been considered advisable to construct this stretch of tunnel in open cut, and additional braces have been placed at the top of the sheathing preparatory to doing so.

The same method of construction will later be extended from the bulkhead at the centre of the river towards the east as soon as the west half is completed, so that traffic can be diverted to that side of the river, thus permitting the closing of the east channel.

This work has progressed at the present time to the following points: From the centre of the river to the west bank almost all of the side sheathing is in; two bulkheads have been constructed and sheathed. The interior bracing and piles supporting it are in place, and the work of sawing off the sheathing in the stretch in the river channel, where the box method is to be used, has been begun, and is progressing satisfactorily. The open trench west of station 140 + 71 is completely sheathed and braced, except that the bulkhead which was to have been constructed at 140 + 71 has been omitted, because the next stretch is to be taken out in open cut. Everything is now ready to pump out the trench from the west bank to the bulkhead at 142 + 06. After this is done, there is only a small amount of excavation to be made at the bottom, when construction work can begin.

THE EFFICIENCY OF SOME ROCKY MOUNTAIN COALS.

By W. H. Williams, Member Montana Society of Engineers.

[Read before the Society, October 11, 1902.*]

It has seemed to the writer that comparative tests of the coals commonly used in Montana would be of considerable service to the coal users of the State. Such tests have been made on most of the coals sold in the State by private parties for their own information; but their data have not been published, and so are of no value to the general public. The average consumer knows nothing of the fuel value of the coal he is using, and frequently pays as much for inferior coal as he would for the best in the market. Tests of this kind, to be of value, should be made by disinterested parties, with all necessary equipment and under conditions uniform for all the samples tested.

The tests from which the following data are taken were made under the supervision of the writer by three seniors of the Montana State College—Messrs. Lee Williams, C. F. Hutton and Wm. Schabarker. The chemical analyses were further supervised by Dr. F. W. Traphagen. In order to get representative samples of coal and to prevent its picking by shippers, lots of coal were purchased (usually a carload) in the open market, ostensibly for the current fuel supply of the college power plant, and without the knowledge of shippers that the coal was to be used for test purposes. While an unusually poor car of coal may sometimes be obtained in this manner, and thus misrepresent the mine, it is undoubtedly the fairest to all concerned. The eleven samples of Montana coals represent practically every productive mine of any magnitude in the State, while the three samples of outside coals represent pretty accurately the various coals shipped into the State at the present time from Wyoming and Canada. Rock Springs coal, for example, fairly represents the Kemmerer and Diamondville coals, as tests made by private parties on these three coals show them to be practically the same in efficiency.

All the tests were run in accordance with the Code of the American Society of Mechanical Engineers. Each run was of ten hours duration, using, as nearly as possible, the full rated power of the boiler. The "alternate" method of starting and stopping was used throughout. The boiler used was a newly installed Abendroth & Root water-tube boiler of 129.6 rated horse-power, with 34 square feet of grate surface and 1296 square feet of water heating

*Manuscript received November 11, 1902.—Secretary, Ass'n of Eng. Socs.

surface. The furnaces were fitted with the McClave shaking and dumping grate. The boiler was in perfect condition, both inside and out, and was well cleaned before the beginning of each test run. The firing was done by an experienced fireman,—the same person firing for all tests.

The coal and ash were weighed on a pair of platform scales. The water was weighed in two galvanized iron tanks of 150 gallons each. The temperature of the feed water was taken by means of a Fahrenheit thermometer in an oil well placed between the heater and the boiler.

The steam pressure, gauge height and fire were kept as nearly uniform as possible, the variations in either case being small. The quality of the steam was determined by a Carpenter throttling calorimeter placed in a vertical steam main close to the drum. Calorimeter readings were taken every thirty minutes, the average reading being taken to represent the quality. The steam pressure was recorded every fifteen minutes.

The sampling of the coal was done in the following manner: From every barrow load of coal a shovelful was taken; this was broken so as to pass through a sieve of quarter-inch mesh, and, by repeated quartering, enough was obtained to fill two one-quart glass fruit jars, this being used for chemical analysis and determination of the calorific value. Fifty pounds of the remainder was put into a galvanized iron tub, placed over the boiler and dried, to determine the approximate moisture. At the end of one week this was re-weighed, the loss in weight being the approximate moisture. In general, this was about three-fourths of the moisture determined by chemical analysis.

The approximate chemical analysis was made in the following manner: A sample was taken from the quart jar, and ground to pass through a twenty-mesh sieve; two grammes of this was put in a porcelain crucible and placed in an oven at 105 degrees C.; at this temperature it required from forty to sixty minutes to drive off the moisture. The crucible was then covered and the volatile matter driven off by the flame of a Bunsen burner. After this it was reduced to ash by a blast lamp, the loss being the fixed carbon and the remainder the ash. Special care was taken in the analysis and everything was done in duplicate, agreeing in all cases to 0.3 per cent. The calorific values were determined by an improved Mahler bomb calorimeter, which was checked up before and after the tests. Here, also, samples were run in duplicate.

In all cases every precaution was taken to obtain correct results, and to get, as nearly as possible, the true values of the different coals.

The following tables, "Summary of Technical Tests" and "Summary of Efficiencies," give all the essential data regarding the different coals:

SUMMARY OF CHEMICAL TESTS.

No.	KIND OF COAL.	Combustible.			Moisture.	Ash.	Heat Units Combustible.	
		Volatile.	Fixed Carbon.	Total.			Calories.	B. T. U.
1	Mountain House Nut......	25.92	48.85	74 77	9.04	16.19	7534.0	13562.0
2	Mountain House Lump....	25.34	52.62	77.96	8.75	13.29	7734.0	13921.0
3	Red Lodge Lump...........	26.24	52.39	78.63	9.23	12.14	7245.0	13042.0
4	Bridger Lump.................	26.55	54.00	80.55	7.67	11.78	7465.0	13438.0
5	Sheridan, Wyo., Lump.....	26.78	46 40	73.18	21.20	5.62	7006.0	12611.0
6	Red Lodge Washed Nut...	26.15	53.52	79.67	9.05	11 28	7205.0	12970.0
7	Chestnut Washed M. R.....	23.10	50.18	73.28	8 64	18 08	8407.6	15133.7
8	Gebo Lump....................	21.46	47.40	68.86	6.42	24.72	8241.0	14834.0
9	Bridger Nut..................	30.00	50.64	80.64	3.95	15 41	7195.5	12952.0
10	Trail Creek (Kountz's) ...	26.24	47.65	73.89	12.41	13.70	7167.0	12901.0
11	Belt Washed Nut..........	22.65	55.00	77.65	4.23	18.12	7445.0	13402.0
12	Galt Lump.....................	24.28	57.45	81.73	8.00	10.12	7421.7	13359.0
13	Rock Springs Lump........	27.90	61.31	89.21	5.64	5.15	7686.0	13836.0
14	Mountain Side, M. R.......	26.84	49.91	76.75	2.71	20.54	7918.0	14252.0

SUMMARY OF EFFICIENCIES.

No.	NAME OF COAL.	Price per Ton.	Evaporated at 212° Fahrenheit, Lbs.	Cost to Evaporate 1000 Lbs. of Water.	Relative Value.*	B. T. U. of Coal.	Boiler Efficiency, Per Cent.
1	Trail Creek (Mountain House) Nut..............................	$2.85	4.65	$0.306	$2.68	10,141	44.27
2	Trail Creek (Mountain House) Lump............................	4.15	5.70	.360	3.28	10,863	50 00
3	Red Lodge Lump..................	4.50	6.50	.345	3 74	10,255	61.00
4	Bridger Lump	4.50	6.10	.371	3.51	10,824	54.30
5	Sheridan, Wyo., Lump............	5.50	5.01	.547	2.88	9,229	52.40
6	Red Lodge Washed Nut.........	3.75	5.40	.346	3.11	10,332	50.60
7	Chestnut Washed M. R...........	3.05	5.30	.288	3.05	11,090	46.50
8	Gebo Lump..........................	4.00	5.75	.346	3.31	10,215	54.40
9	Bridger Nut..........................	3.75	4.86	.386	2.80	10,444	44.80
10	Trail Creek (Kountz's) Lump...	4.50	5.44	.413	3.13	9,533	55.00
11	Belt Washed Nut...................	†4.50	5.60	.400	3.22	10,406	52 00
12	Galt, Canada, Lump...............	†6.50	6.05	.535	3.49	10,919	53.10
13	Rock Springs, Wyo., Lump.....	†6.75	7.55	.447	4.35	12,343	59.00
14	Mountain Side, M. R.............	3.40	5.78	.294	3.32	10,938	51.00

*Compared to Chestnut Washed Mine Run. †Price in Butte.

As will be seen from the tables, the most economical steam coals were the Chestnut and Mountain Side. These are mined on the properties recently acquired by the Northern Pacific railway. The Sheridan and Galt coals are the least economical of the lot. In fact, they are so expensive as to be out of the question as steam coals. The Galt coal also makes such bad clinkers as to rule it out as a steam coal.

The tables show pretty conclusively that a great many coals are being sold for more than they are worth in the markets of the State. For instance, the lump coals from Trail Creek, Red Lodge, Bridger and Gebo usually retail at $4.25 to $5.00 per ton, while Galt, Sheridan and Rock Springs lump bring from $6.00 to $6.75 per ton. As a matter of fact, Sheridan coal is worth less, Galt about the same and Rock Springs about $1.00 per ton more than those first named.

Coal users would do well to consult this table of efficiencies when purchasing fuel. It is likely to save them some money. Large consumers would save money by purchasing coal on test showings. It is not a very difficult matter to rig up a boiler, or a battery of boilers, for testing purposes, and it will pay to test coal in a rational manner. The amount of water evaporated per pound of coal is the only true test of its fuel value. The testimony of the average fireman is utterly unreliable on this point. Nor does chemical analysis show what the coal may do under a boiler. The Galt coal, for example, shows better by chemical analysis than either the Red Lodge or Bridger lump coals, yet under a boiler it is poorer than either of them, largely owing to the bad clinker which is formed.

Incidentally, these tests show that there is not a coal mined in Montana, at the present time, that will evaporate seven pounds of water from and at 212 degrees F. The nut and Mine Run coals, which are used mostly for steam purposes, will evaporate only five pounds to six pounds. I am aware that some tests made by private parties have shown higher results than we have been able to get; but in every case of this kind either the coals were picked or else the furnace was of some special construction conducing to fuel economy. We took pains to make these tests under good representative service conditions,—such conditions as might and should prevail at every steam plant in this State.

OBITUARY.

Colonel G. H. Mendell.

Member of the Technical Society of the Pacific Coast.

Colonel George H. Mendell was called to his last rest on October 19, 1902. His death followed a very brief illness and marked the termination of an active, useful life.

He was born in Pennsylvania October 12, 1831; graduated from the U. S. Military Academy in 1852, and was in active service in the Engineer Corps of the U. S. Army from that time until his retirement in 1895. He was Assistant Topographical Engineer on the survey of the northwestern lakes in 1852-54, then on the staff of Major-General Wool, commanding the Department of the Pacific in 1854, at which time the advantages of the Pacific Slope made a lasting impression on his mind.

He was thereafter assistant on a railway exploration survey from San Francisco to Fort Yuma, and later, in 1855 and 1856, on an expedition against hostile Indian tribes in Oregon and Washington Territories. From 1856 to 1858 he was in charge of the construction of military roads in Oregon and Washington Territories. He was then called to the Military Academy at West Point and served there as Assistant and Principal Assistant Professor of Natural and Experimental Philosophy.

At the outbreak of the war of the Rebellion he was assigned to Colonel Miles' Division in the Manassas campaign, and thereafter rendered valuable service on special duty and in command of the U. S. Engineers' Battalion in reconnoissance work, building, guarding and destroying bridges, constructing batteries, block houses, rifle trenches, making and repairing roads and in carrying on siege operations at Petersburg, Va. He was Assistant Engineer on the defenses of Baltimore, Md., in 1864. After again serving as instructor in the Military Academy for a year, to which duty he had been assigned to recover from disabilities incurred in the field, he was for a brief period Superintending Engineer of harbor defense works at New Bedford, Mass., and of the work for the preservation of Plymouth Beach.

On January 1, 1867, he took charge of the fortification work of Alcatraz Island and Lime Point, in San Francisco Harbor, and, soon after, of the defenses at the mouth of Columbia River and of Fort Point, San Francisco.

His subsequent active work on the Pacific Coast is so well known to our members that but little further need be said, other than that his activity was not confined to his Government work, which included the Wilmington Harbor breakwater, examination and survey of Estero Bay and San Diego Harbor, the removal of Rincon Rock in San Francisco Bay, the improvement of Oakland Harbor and of Sacramento and Feather Rivers and of the construction of San Francisco Harbor defenses.

Colonel Mendell was a member of the Commission appointed in 1874 to examine the irrigation possibilities in California. He was a member and President of the first California Débris Commission to regulate hydraulic mining. He was on the Commission to select a site for a naval dry dock on the Pacific Coast north of Latitude 42 degrees, and on the Commission to select a site for a military post in San Diego, Cal., and of the Board of Engineers for the planning of Pacific Coast defenses.

Colonel Mendell was consulted by the city and county of San Francisco in reference to the sufficiency of the City Hall concrete foundation. He was in 1876-77 entrusted by this city with the examination of possible sources of water supply and made an exhaustive report, which has proved of great value to the city. From 1878 to 1880 he was Consulting Engineer to the State of California, acting as an adviser to the State Engineer, who was charged with the investigation of irrigation, drainage and mining débris problems. He was also a member of the Sewerage Commission for the city and county of San Francisco, appointed in 1892 by the Board of Supervisors.

At the time of his retirement he was the Senior Colonel in the Engineer Corps of the U. S. Army.

Among the works with which he was more or less prominently connected as Consulting Engineer subsequent to his retirement may be mentioned the Portland Water Works, the appraisement of the Los Angeles Water Works, examination of the water supply possibilities for Berkeley, a drainage project for Reclamation District, No. 108, in the Sacramento Valley, and the Red Bluff Water Works.

He was selected by Mayor James D. Phelan to serve under a new city charter as President of the first Board of Public Works for the city and county of San Francisco from January 8, 1900, for three years. His efficient service in organizing this new department, which benefited by his long experience, his thoroughness as an engineer and his ripe judgment, are thoroughly appreciated by

those who have been in position to judge of results. His term of office was drawing to a close at the time of his death.

Colonel Mendell was one of the founders of this Society. His attainments and his standing in his profession were fittingly recognized when he was made our first President in 1884. He served in this capacity for two terms.

Our estimate of Colonel Mendell's worth and appreciation of his professional work is fittingly expressed in the words of the Chief of the Engineers Corps of the U. S. Army, who, in sending out notice of his death, says:

"Colonel Mendell's record for distinguished service, his high attainments, his purity of life and his sincerity of purpose in all matters relating to either private or public official work have never been excelled by any officer whose record has appeared upon the rolls of the army."

C. E. Grunsky,
Marsden Manson,
Otto von Geldern,
Committee.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XXIX. JULY, 1902. NO. 1.

PROCEEDINGS.

Engineers' Club of Minneapolis.

158TH MEETING, MINNEAPOLIS, JUNE 14, 1902.—This meeting was in the nature of an inspection of the New Pumping Station being built by the city of Minneapolis. Mr. Geo. W. Sublette, City Engineer, under whose supervision the work is being done, showed the members the work completed to date. This consisted of the intake foundations for the entrance of water from the river and the foundations for the pumps and boiler house. These foundations are on piles placed in a clay and treacherous soil, calling for large, broad and costly foundations.

When this new pumping station is completed and two 15,000,000-gallon Holly pumps installed, the lower or city pumps will be abandoned and Minneapolis will be assured of a better and an ample supply of water.

The Club inspected the foundations and the plans, and discussed the merits of the construction, adjourning after a vote of thanks to the City Engineer.

159TH MEETING, MINNEAPOLIS, JULY 19, 1902.—This meeting was in the nature of an inspection of engineering on the North Side.

The Club first visited the old Camden place pumping station. There are installed here two Worthington horizontal 10,000,000-gallon pumping engines and Morison internal furnace boilers, burning green and wet ground pine refuse in a Dutch oven, the fuel being fed automatically.

The trip embraced a visit to the C. A. Smith Lumber Co.'s immense saw mill, which is equipped with the most modern machinery and uses every scrap of the pine log for some useful purpose. The box industry was of special interest. Here board boxes were sawed, resawed, planed, tongued and grooved, fitted together and nailed, all automatically, and then delivered "knock down" ready for shipment.

The city garbage crematory, built from designs and patents of DeCarrie, was also inspected. This crematory is a success, operates cheaply and well, and entirely without odor.

From notes in the minutes of the Club by

W. S. PARDEE, *Secretary pro tem.*

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JOHN C. TRAUTWINE, Jr., Secretary,
257 SOUTH FOURTH STREET,
PHILADELPHIA.

Association of Engineering Societies.

Vol. XXIX. **AUGUST, 1902.** No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., August 1, 1902.—Held in the hall of the Mechanics' Library, and called to order at 8.30 p.m., by Past-President Grunsky.

The minutes of the last regular meeting were not read, the record book having been misplaced by the office attendant.

Mr. R. G. Doerfling applied for membership, proposed by Hermann Barth, C. E. Grunsky and Otto von Geldern.

Mr. Ralph Warner Hart addressed the Society on the subject of "Steel Construction of Tall Buildings," which was discussed.

The paper by Mr. John Richards on "Rotative Pumping," having been circulated for discussion, was responded to by L. J. Le Conte and A. E. Chodzko, whose written discussions were read by the Secretary.

Meeting adjourned.

Otto von Geldern, *Secretary.*

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JOHN C. TRAUTWINE, Jr., Secretary,
257 SOUTH FOURTH STREET,
PHILADELPHIA.

Association
of
Engineering Societies.

Vol. XXIX. **SEPTEMBER, 1902.** No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, September 17, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M. Vice-President Frederick Brooks in the chair; ninety-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Edward A. Buss, Frank B. Dowst, Benj. W. Ellis, Edward J. Johnson, Samuel J. Mott, Calvin B. Pratt and George V. White, were elected members of the Society.

The Secretary read a communication from the Superintendent of the Tremont Temple, asking the Society to change the date of its October meeting on account of a large convention, which desired the use of all the halls in the Temple during the third week in October.

On motion of Mr. French it was voted to hold the next regular meeting on October 22d.

The Chairman announced the death of Frank E. Fuller, and, on motion, the President was requested to appoint a committee to prepare a memoir.

Mr. Howard A. Carson then gave a very interesting account of various methods used in constructing tunnels under water and spoke particularly of the work of the East Boston Tunnel now in progress. The talk was illustrated by lantern slides.

Mr. John F. Rourke, of New York, a Director of the American Society of Civil Engineers, was then introduced and spoke entertainly of two methods of tunnel construction which he had planned. He illustrated his remarks by a number of lantern slides. At the conclusion of his remarks the thanks of the Society were extended to him for his courtesy in appearing before the Society.

Mr. John Ericson, City Engineer, of Chicago, was introduced and gave a brief account of the tunnels now under construction in the streets of Chicago for telephone purposes.

Adjourned. S. E. Tinkham, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, September 5, 1902.—Regular meeting of the Technical Society of the Pacific Coast called to order at 8.30 o'clock p.m., by President D. C. Henny.

The minutes of the last regular meeting and of the June meeting were read and approved.

Mr. R. G. Doerfling, a civil and mechanical engineer, was elected to membership in the Society upon a count of ballots.

Mr. John Richards, consulting mechanical engineer, brought up the subject of Bay Steamers, and the adequacy of the present construction for the purpose, with special reference to the San Francisco Ferry Steamer "Tamalpais"; drawing comparisons between different types, such as paddle-wheel steamers, wheels with feathering blades and screw propellers. The matter of the machinery was also discussed, referring to the beam engine as the most practical and effective and to the direct oscillating cylinders as the most economical and space-saving designs. The preference for any particular type being usually a matter of evolution in the particular locality in which it was made use of.

The position of the consulting engineer and his relation to the boat builders and designers were also made a matter of special criticism, and the final conclusions were submitted to open discussion, which was taken part in by Geo. W. Dickie and C. E. Grunsky.

Mr. Dickie referred to the matter of papers for the Society, stating that more energy would have to be shown in obtaining them, if the meetings are expected to be well attended. The Secretary stated that Professor C. B. Wing, of Stanford University, had informed him by letter that Mr. F. S. Edinger had promised a paper for the October meeting on the "Erection and Field Riveting of Modern Steel Bridges," which could not be obtained in time for the September meeting.

The unfortunate death of our fellow member A. Schierholz was announced, and it was agreed, subsequent to the meeting, that Geo. W. Dickie, C. E. Grunsky, H. D. Connick and Otto von Geldern form a committee to draw and submit suitable resolutions in memory of the deceased member.

Likewise were expressions of regret recorded for the late James Spiers, who had been a member of the Technical Society for many years. from its first organization and opening of the charter, and who resigned for reason of ill health about six months ago.

Resolutions in memory of these two able engineers and worthy men are to be recorded and spread upon the minutes.

Adjourned.

Otto von Geldern, *Secretary.*

Association

of

Engineering Societies.

Vol. XXIX. | October, 1902. | No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

547th Meeting, St. Louis, September 17, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 p.m.

Present, twenty-one members and four visitors. In the absence of the President and Vice-President, the meeting was called to order by the Secretary. Mr. B. H. Colby was elected as Chairman of the meeting.

The minutes of the 546th meeting were read and approved. The minutes of the 332d, 333d and 334th meetings of the Executive Committee were read. The minutes of the 6th, 9th, 10th, 11th, 12th and 13th meetings of the Governing Board were read.

The applications of Messrs. A. H. S. Cantlin, Frank T. Adler and D. Edward MacCarthy were read and referred to the Executive Committee. Messrs. L. F. Goodale and A. P. Greensfelder were, on ballot, elected to membership.

The Secretary read a communication from Mr. J. A. Ockerson, Chief of the Department of Liberal Arts, Louisiana Purchase Exposition Company; the matter was referred to the Executive Committee for their suggestions and recommendations.

The Prize Committee submitted a report, which was accepted. Upon motion the Chairman was instructed to appoint a committee to revise the rules governing the award of an annual prize so as to eliminate the feature of a gold medal. The Chairman appointed Mr. Roper on this committee.

The Secretary read an invitation to the Jubilee Meeting of the North of England Institute of Mining and Mechanical Engineers to attend the jubilee meeting in connection with the annual meeting of the Institute of Mining Engineers, and also to attend a conversazione of the same society.

On motion, duly seconded, a vote of thanks was tendered to the St. Louis Railway Club for its invitation to the Engineers' Club to join them in their excursion to the World's Fair Grounds on September 12th.

The Chairman then introduced Mr. Burt Cole, who read a paper on "Bituminous Coal Mining in Illinois." For the year ending July 1, 1901. there were 915 mines in operation in Illinois, employing over 44,000 men and boys and mining about 26,000,000 tons. The death rate from accident was

about 2.2 per one thousand employes, or one death for 269,000 tons. Nearly 60 per cent. of the deaths are due to falling rock, coal or slate. Coal is mined by two general systems: the long-wall and the pillar-and-room system. The long-wall system requires thin veins, an elastic roof, and considerable refuse; it mines about 90 per cent. of the coal. The system is used in a few mines in the northern part of the state. The pillar-and-room method is the more common method, but mines only about 50 per cent. of the coal. This system of mining was described in considerable detail. By means of lantern-slides, surveys of mines using this system were shown, and the method of ventilating described.

Mechanical haulage is rapidly replacing mule haulage along the main entry. The endless rope, tail rope and electric systems of haulage were described. A number of machines for undercutting coal were illustrated and their use was explained. The methods of surveying were given in some detail, and the paper closed with a few remarks on the labor conditions.

In the discussion which followed Messrs. Fish, Freeman, Barwick, Bausch, Russell and others participated.

The meeting then adjourned to an adjoining room, where a lunch had been provided by the Entertainment Committee.

D. W. Roper, *Secretary.*

549th Meeting, St. Louis, October 15, 1902.—Held at the rooms of the Club, 709 Pine street, at 8.25 p.m. Vice-President Van Ornum presiding.

Present, twenty-three members and five visitors.

The minutes of the 548th meeting were read and approved. The application for membership of Louis C. F. Metzger was read and referred to the Executive Committee.

The subject of the evening was a paper by Dr. A. P. Winston on "The Good and Evil of Trades Unions." The speaker discussed the different methods of regulating wages and the advantages and disadvantages of each system both to the workmen and their employers. An interesting discussion followed the paper in which Messrs. Hermann, Moore, Bouton, Van Ornum, Reber, Wheeler, Bryan and Colby participated.

The meeting adjourned to an adjoining room where light lunch was served.

E. B. Fay, *Secretary pro tem.*

Engineers' Club of Minneapolis.

160th Meeting, Minneapolis, September 13, 1902.—This meeting was in the nature of an inspection of the extensive quarries of the Minnesota Sandstone Company. These quarries are on the Kettle River, about 100 miles north of Minneapolis, at Sandstone, Minn.

Transportation was provided by courtesy of the Great Northern Railway Company, who set aside a special car for the thirty-five members and ten visitors who attended.

The Minnesota Sandstone Company, through its manager, George W. Bestor, and Secretary Charles S. Hale, entertained the members of the Club in the proper style. Everything was provided for the Club in a social way, and the engineering and geological features of the quarries were shown to their advantage.

The power plant for the quarries has a 300 H. P. turbine and about 200 H. P. in engine capacity. Compressed air is used extensively for drilling and moving the material. The stone is used extensively for general building purposes, bridge abutments, for curbing and as a paving material. In the latter case the blocks are cut and dressed in much the same manner as for other stone pavements, but are more uniform in size and have better dressed faces. The pavement is not slippery and open joints are not necessary to give a footing.

The stone is extensively used in the state. The quarrying of same and a study of the stone at the quarries was therefore of great interest to the members of the Club.

The following members, all residing in Minneapolis, have been elected and have qualified as active members of the Club: G. R. Scott, electrician at Court House and City Hall; J. E. Egan, civil engineer and surveyor; H. G. Decker, estmator with American Bridge Company; Hugo Arnold, architect with F. D. Orff; N. W. Rose, student in Mechanical Engineering, State University; Frank H. Nutter, landscape architect; W. C. Kaercher, draftsman, American Bridge Company; J. J. Flohil, draftsman, American Bridge Company; O. P. Bailey, draftsman, American Bridge Company; M. B. Stone, draftsman, American Bridge Company; W. F. Burrill, draftsman, American Bridge Company.

Net gain in 1902 membership, twenty-eight.

Edward P. Burch, *Secretary.*

Boston Society of Civil Engineers.

Boston, October 22, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 P.M., President George A. Kimball in the chair; fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Willard Kent and Morton F. Sanborn were elected members, and Mr. Charles S. Robbins was elected an associate of the Society.

A letter was read from Mr. Alfred D. Flinn, resigning the office of Librarian of the Society on account of removal to New York city. The resignation was accepted.

On motion of Professor Allen the President was requested to appoint a committee of three to nominate a candidate for Librarian. The committee appointed consisted of Messrs. A. H. French, R. A. Hale and F. M. Miner.

The Secretary read a communication from Mr. J. A. Ockerson, Chief of Department of Liberal Arts of the World's Fair, at St. Louis, urging the Society to take such steps as may be deemed necessary to make a creditable exhibit at the exposition of the work of its members. On motion of Mr. Stearns, it was voted to refer the matter to the Board of Government with full powers.

On motion of Mr. Higgins, the thanks of the Society were voted to the Water Commissioners and the Superintendent of the Natick Water Works, and to the contractors engaged in the work, Mr. F. A. Snow and Messrs.

McClellan & Hennessey, for courtesies shown the members of the Society on the occasion of the visit to the new supply well and reservoir, on October 15th.

The paper of the evening was then read by its author, Mr. Edmund K. Turner, entitled "The Abolition of Grade Crossings in Massachusetts."

A very interesting discussion followed in which Messrs. John W. Ellis, J. W. Rollins, Jr., H. Bissell, G. F. Swain, W. F. Williams, R. R. Evans, C. F. Allen, Henry Manley and I. M. Story and others took part.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., October 11, 1902.—A regular meeting of the Montana Society of Engineers was held at the Society's room in the Tuttle Block; President Harper in the chair.

The Secretary being absent the President appointed H. M. Patterson Secretary *pro tem.*

The minutes of the last meeting were read and approved.

Moved by Mr. Carroll that a committee of two, with the President, be appointed to select a place for the next annual meeting.

Motion carried.

The President appointed Messrs. Carroll and Moore.

Professor Williams, of Bozeman, then presented his paper on "The Efficiency of Some Rocky Mountain Coals."

An interesting discussion followed by Messrs. Goodale, Winchel, Carroll, Sickles, Moore, Blossom, Harper and others.

Mr. Frank gave an interesting account of the coal fields in Frank, Alberta, Canada.

Society adjourned. H. M. Patterson, *Secretary pro tem.*

Association of Engineering Societies.

Vol. XXIX. **November, 1902.** No. 5.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, November 7, 1902.—Called to order at 8.30 p.m. by President Henny.

No meeting was held in October.

The minutes of the last regular meeting were read and approved.

The President announced with expressions of great regret the death of the late Colonel G. H. Mendell, the first President of the Technical Society, and appointed the following committee to draw suitable resolutions in memory of the deceased: Marsden Manson, C. E. Grunsky and Otto von Geldern.

The President thereupon stated to the members that this meeting had been called for the special purpose of discussing the various features of the "Irrigation Bill" as proposed by the Water and Forest Association Committee, calling attention to the great importance of this measure, particularly to the engineering profession of the State.

After the Secretary had read the introduction to the bill, and the headings of the different sections of the proposed measure, the discussion was opened by Mr. Marsden Manson, followed by C. E. Grunsky, Mr. Adams, Luther Wagoner, A. T. Herrmann and others.

Mr. Herrmann called particular attention to the first section, which declares the state ownership of water, including the water of all streams, whether flowing above or underground in known or defined channels. He referred to the difficulty of defining an underground flow, and its conflict with artesian wells, which might in all equity be claimed by the owner of the property upon which such wells are located, and that any attempt of the State to claim such water as underground flow would be met by considerable opposition, particularly in counties where irrigation is principally accomplished by means of wells.

This feature and many others of the large scope of the bill were discussed at length. Mr. Wagoner thought that under its present condition, covering many diversified points, the measure would not be likely to pass the Legislature; while other members expressed the opinion that the

names of the prominent men on the committee, including two Chief Justices of the Supreme Court of California, two Presidents of the principal universities of the State, two of the leading professors of Engineering and two irrigation experts of the Federal Government, carried with it sufficient weight and guaranteed that a measure so universally desired would be passed without opposition.

The discussion of the bill was finally limited to four special lines, and divided into four classes, with special committees to study these individual features, and report the results of such investigation and probable recommendation back to the Society; a meeting for the purpose of hearing these committee reports, and for further discussion of the bill to be held on November 21, 1902. Mr. Gutzkow made this motion, which was carried.

The President subsequently selected the following committees:

1. On the Appropriation of Water and the Declaration of Ownership:

C. E. Grunsky, A. T. Herrmann and C. D. Marx.

2. On the Fixing of Water Rates:

Marsden Manson, Stephen E. Kieffer and C. D. Marx.

3. On the Control by an Appointed Board of Engineers:

C. E. Grunsky, L. J. Le Conte and C. D. Marx.

4. On the Practical Method of Carrying Out the Law as Defined in the Bill:

Marsden Manson and A. T. Herrmann.

The meeting thereupon adjourned to meet in two weeks, on Friday evening, November the twenty-first.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

548th Meeting, St. Louis, October 1, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 p.m., with Vice-President Van Ornum in the chair. Present, twenty-nine members and fourteen visitors. The minutes of the 547th meeting were read and approved. The minutes of the 335th meeting of the Executive Committee were read. The application of Mr. W. O. Renken was read and referred to the Executive Committee. Messrs. A. H. S. Cantlin, F. T. Adler and D. E. MacCarthy were elected to membership. Mr. Roper, the committee appointed to revise the rules concerning the award of an annual prize, made a report, which was accepted.

The Chairman then introduced Mr. R. H. Phillips, who addressed the Club on the subject, "Some Engineering Features of the Exposition Grounds." Mr. Phillips exhibited maps and drawings showing the progress of work to date. The disposal of the River Des Peres and the means for the prevention of floods by the removal of obstructions below the Exposition grounds were described. The layout of the system of sewers and water for domestic and fire purposes, roads, lagoons, cascades, conduits for electric wires and railroad tracks were shown by means of the maps and the engineering features were considered. In the discussion which followed a large number of the members participated.

A light lunch was served after the meeting.

D. W. Roper, *Secretary.*

550TH MEETING, ST. LOUIS, NOVEMBER 5, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 P.M., with Vice-President Van Ornum in the chair. Present, forty-two members and nine visitors. The minutes of the 549th meeting were read and approved. The minutes of the 336th meeting of the Executive Committee were read; included in the minutes was a report in favor of the Club having a booth in the Liberal Arts Building at the World's Fair, the booth to be furnished and decorated in appropriate manner, and to be in charge of an attendant. On motion the report of the committee was adopted, and the Executive Committee authorized to make the necessary arrangements.

The Chairman then announced that nominations for members of the Nominating Committee of five members, to be chosen by ballot, as provided in Section 2 of the By-laws, were in order. Messrs. Russell, Brenneke, Humphrey, Spencer, Fay, R. H. Phillips, Barwick, Pfeifer, Henby and Wise were placed in nomination. The first five named were on ballot elected; Mr. Humphrey, having received the largest number of votes, was declared chairman.

Messrs. L. C. F. Metzger and W. O. Renken were on ballot elected to membership.

The paper of the evening, "The St. Louis Water Problem," was then presented by Mr. R. E. McMath. This paper will appear in full in the JOURNAL. The paper was discussed by Messrs. Flad, Robert Moore, Colby, Ockerson, S. B. Russell, Kessler, Wheeler and A. L. Johnson.

Upon conclusion of the discussion the meeting adjourned to an adjoining room, where a light lunch was served.

D. W. ROPER, *Secretary.*

551ST MEETING, ST. LOUIS, NOVEMBER 19, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 P.M., with President Kinealy in the chair. Present, thirty-seven members and thirteen visitors.

The minutes of the 550th meeting of the Club were read and approved. The minutes of the 336th meeting of the Executive Committee were read.

The Nominating Committee reported the following list of nominations for officers for the ensuing year:

President—J. L. Van Ornum.

Vice-President—J. A. Ockerson.

Secretary—H. J. Pfeifer.

Treasurer—E. E. Wall.

Librarian—E. B. Fay.

Directors—D. W. Roper and S. E. Freeman.

Members of the Board of Managers of the Association of Engineering Societies—E. R. Fish and F. E. Bausch.

On motion of the Librarian, a vote of thanks was tendered to Mr. Julius Baier for his donation of books, pictures, etc., to the Club, and the Secretary was instructed to notify Mr. Baier of the action of the Club.

The Chairman then introduced Mr. J. C. Robinson, who presented a paper entitled "A Brief Review of the Manufacture of Hydraulic Cement, Its Chemistry, History and Recent Development." A number of figures were given of the growth of the cement business showing that the use of Portland cement was increasing at a more rapid rate than all others. Several classes of cement were described and their uses were classified. For

hydraulic cement the chemical composition in some detail was given, as well as the effect of the various constituents upon the properties of the cement. The early methods of manufacture, as practiced several centuries ago, were described. The various improvements that have been made in the manufacture and their effect on the cost and time of manufacture were also given. The most modern methods of cement manufacture, including the rotary kiln, were described in some detail. A description was given of the method of testing employed by the manufacturers and a statement of the accuracy required in mixing the materials.

In the discussion which followed the paper, Messrs. Colby, Wheeler, S. B. Russell, Affleck and A. L. Johnson participated. The discussion served to elucidate some further points regarding the effect of the various chemicals and storage upon the properties of cement.

Mr. S. B. Russell then presented a resolution regarding the keeping by the Club of a classified index of engineering periodicals. On motion of Mr. Van Ornum the resolution was altered as follows: *Resolved,* That a committee of three, including the Secretary, be appointed by the Chairman to consider methods and cost of keeping a classified index, and to report to the Club. The Chair appointed Messrs. S. B. Russell, Van Ornum and Roper on this committee.

The meeting then adjourned to an adjoining room, where a light lunch was served.

D. W. Roper, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXIX. **DECEMBER, 1902.** No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

BOSTON, MASS., NOVEMBER 19, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 P.M., President George A. Kimball in the chair; ninety-four members and visitors present.

Record of the last meeting was read and approved.

The committee appointed at the last meeting to nominate a Librarian to fill a vacancy, reported the name of Mr. Frank P. McKibben. On motion of Mr. Sidney Smith, the Secretary was directed, by a unanimous vote, to cast a ballot for F. P. McKibben for Librarian. The Secretary having performed the duty assigned him, the President announced the election of Mr. McKibben as Librarian.

Mr. X. Henry Goodnough then read the first paper of the evening entitled, "A Description of Sewage Disposal Systems in Massachusetts," which was fully illustrated by lantern slides.

Mr. F. Herbert Snow read the second paper entitled, "Adaptability of Massachusetts Methods to Sewage Disposal Problems in other States."

Mr. Harrison P. Eddy, superintendent of sewers, of Worcester, spoke of the sewerage problem in that city. A general discussion followed in which the following members took part: Messrs. George A. Carpenter, Freemen C. Coffin, L. P. Kinnicutt, Otis F. Clapp, F. P. Stearns and J. L. Woodfall.

Adjourned. S. E. TINKHAM, *Secretary.*

BOSTON, MASS., DECEMBER 17, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 P.M. President George A. Kimball in the chair; one hundred and fifty-eight members and visitors present, including ladies.

Record of the last meeting was read and approved.

Mr. Charles D. Elliot was elected a member and Mr. Arthur C. Townsend an associate of the Society.

The paper of the evening was read by Mr. Elmer L. Corthell entitled, "Argentina: Past, Present and Future." The paper was profusely illustrated with lantern slides, many of them beautifully colored.

Adjourned. S. E. TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

552D MEETING, ST. LOUIS, DECEMBER 3, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 P.M., with Vice-President Van Ornum in the chair. Present, twenty-seven members and two visitors.

The minutes of the 551st meeting of the Club were read and approved. The minutes of the 338th meeting of the Excutive Committe were read.

The Chairman then announced that the Executive Committee had approved the report of the Committee on Prizes, and that he was pleased to announce the award of the annual prize to Mr. H. H. Humphrey for his paper entitled "Notes on the Use of Beaumont Oil as Fuel," read before the Club April 2, 1902.

The applications of Messrs. T. M. Meston, R. L. Murphy, E. G. Helm and R. H. Fernald were read by the Secretary and referred to the Executive Committee.

Mr. Russell, Chairman of the Committee on Engineering Index, made a report, which was received and filed. Further action on the recommendations was deferred until a later meeting.

In accordance with Section 11 of the By-Laws, the names of the candidates for offices for the ensuing year, which had been submitted by the Nominating Committee at the preceding meeting, were read by the Secretary, and were placed in nomination. On account of leaving the city, Mr. D. W. Roper asked unanimous consent to withdraw his name from the ballot as a candidate for director; there being no objection, the Chairman announced that the privilege would be granted. The Chairman then called for further nominations.

The name of Mr. W. G. Brennecke was proposed as a candidate for director in a communication signed by Messrs. Humphrey, Fay, S. B. Russell, Flad and Spencer. There were no further nominations.

The Chairman then announced that the next order of business would be the reading of the annual reports of officers and standing committees. As the President of the Club was absent from the city, the annual report of the Executive Committee was not presented. The reports of the Secretary, Treasurer, Librarian, Board of Managers and Governing Board were read and on motion were accepted and filed. The Treasurer's report was referred to the Executive Committee for auditing.

On motion it was voted to hold the annual banquet at the meeting on December 17, 1902, the price not to exceed $3.50 per plate. The Chairman appointed Messrs. Zeller and Klauder a Committee on Time and Place, and Messrs. Flad and Layman a Committee on Program.

The meeting then adjourned to an adjoining room, where a lunch was provided by the Entertainment Committee.

D. W. ROPER, *Secretary.*

Technical Society of the Pacific Coast.

SPECIAL MEETING, NOVEMBER 21, 1902.—Called to order at 8.30 P.M. for the purpose of discussing the Water and Forest Association's proposed irrigation bill.

The minutes of the last regular meeting were read.

The committee appointed to draw up suitable resolutions of respect in memory of the late Colonel G. H. Mendell, first President of the Society, presented its report. These resolutions were read by the Secretary, while the Society rose to its feet and remained standing. It was ordered that these resolutions be spread in full upon the minutes, that they be published in the Journal of the Association of Engineering Societies, and that a copy be sent to the family of the late Colonel Mendell.

The discussion of the proposed irrigation bill was then taken up, and the reports of the committees were read and accepted. Each topic as brought up by its special committee was then discussed in detail, Professor Marx, as one of the framers of the bill, answering such questions as were requested for the information of the members discussing the bill.

A full stenographic report of the discussion was taken down for reference and for the purpose of writing therefrom the suggestions as to changes and modifications of the bill, which will be laid before the Water and Forest Association for its consideration.

The committee of this association will be called together before Christmas for the purpose of considering any suggestions that may be brought to its notice.

No further business appearing, the meeting adjourned.

Otto von Geldern, *Secretary.*

San Francisco, Cal., December 5, 1902.—Regular meeting called to order at 8.30 p.m. by Past President Grunsky.

The minutes of the last regular meeting were read and approved.

Applications for membership from Leon S. Quimby, proposed by C. E. Grunsky, Harry Larkin and Otto von Geldern, and from Morris Kind, proposed by Adolf Lietz, E. J. Schild and Otto von Geldern, were read and referred to the Board of Directors.

The following committee was selected to nominate officers for the ensuing year: C. E. Grunsky, Marsden Manson, Hermann Meyer, F. C. Herrmann and Edward F. Haas.

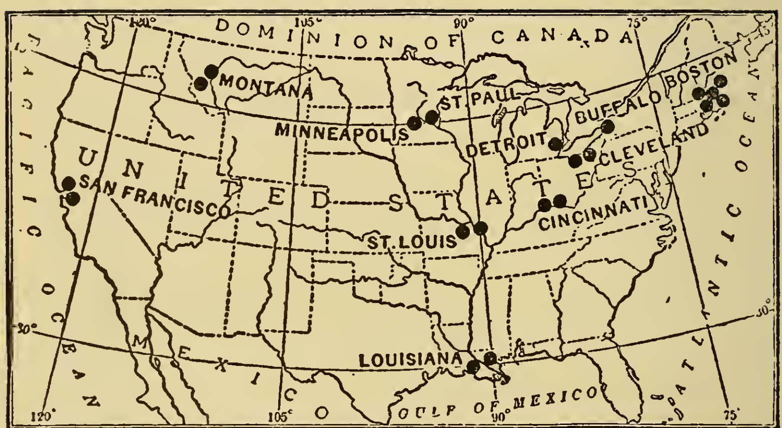
Mr. Grunsky reported the present session of the Water and Forest Association and the business done on this day as far as he had learned. The reports of the committees were again referred to and the matter of co-operation with the Association outlined.

Mr. Manson stated that he would arrange for a visit of the Society to the cable-laying vessel now in the harbor; while Mr. Haas related some of the methods employed in trans-oceanic cable laying by this Company. The Secretary will be informed of the time and place of the visit and will notify the members thereof.

The Secretary referred to a paper written by Mr. Hans C. Behr, member of this Society, whose able theoretical discussion of "Winding Plants for Great Depths" in deep-level mining operations, had been read before the Institution of Mining and Metallurgy, at the rooms of the Geological Society, London, on May 15, 1902, and had there been considered as meritorious and had been awarded the prize. The congratulations of the Society were tendered to Mr. Behr.

Meeting thereupon adjourned.

Otto von Geldern, *Secretary.*


DOMINION OF CANADA
MONTANA
MINNEAPOLIS
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DETROIT
BUFFALO
BOSTON
CLEVELAND
UNITED STATES
SAN FRANCISCO
ST. LOUIS
CINCINNATI
LOUISIANA
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
GULF OF MEXICO
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